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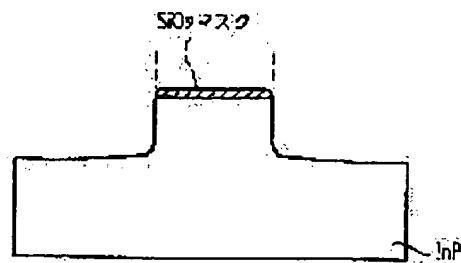
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(54) ETCHING OF COMPOUND SEMICONDUCTOR, SEMICONDUCTOR LASER ELEMENT, AND MANUFACTURE THEREOF

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a method for dry-etching a compound semiconductor to form a vertical, smooth etched surface thereof.

SOLUTION: In the etching method, a dry etching apparatus having a plasma generation source for generating plasma having a density of about 10^{10}cm^{-3} or more is used to subject a family III-V compound semiconductor or a family II-VI compound semiconductor to a dry etching process with use of a mixture of a gas containing halogen elements and a nitrogen gas. At this time, it is set to approximately satisfy a relationship of $(\text{flow rate of a gas containing halogen elements})/(\text{flow rate of nitrogen gas}) \geq 1$, and a pressure in the etching reaction is set at about 1mTorr or more.



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CLAIMS

[Claim(s)]

[Claim 1] It is the etching approach that it is the etching approach which carries out dry etching of a group III-V semiconductor or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies, and is (the flow rate of the gas containing a halogen) / (flow rate of nitrogen gas) about ≥ 1 , and the pressure under etching reaction is about 1 mTorr or 1 or more mTorr.

[Claim 2] The etching approach according to claim 1 which accelerates the ion generated in said source of the plasma, and is etched with the kinetic energy of this accelerated ion while heating a sample front face.

[Claim 3] The etching approach according to claim 1 which accelerates the ion generated in said source of the plasma, heats only near the front face of the sample containing an II-VI group compound, and cools the susceptor of this sample with the kinetic energy of this accelerated ion.

[Claim 4] The etching approach according to claim 1 etched while heating sample susceptor.

[Claim 5] the 1st dry etching process which accelerates with the 1st acceleration voltage and etches the ion generated in said source of the plasma -- this -- the 2nd dry etching process which carries out after the 1st dry etching process, accelerates the ion generated in this source of the plasma with the 2nd acceleration voltage, and is etched -- further -- including -- **** -- the etching approach according to claim 1 that this 1st acceleration voltage is larger than this 2nd acceleration voltage.

[Claim 6] The etching approach according to claim 1 which includes the 1st etching process which performs dry etching according to claim 1, and the 2nd etching process which performs wet etching.

[Claim 7] Said dry etching system is the etching approach according to claim 1 of having the source of a radical beam, and the source of an ion beam, and performing dry etching while controlling independently the consistency of the radical generated by this source of a radical beam, and the consistency of the ion generated by this source of an ion beam, respectively.

[Claim 8] Said compound semiconductor is the etching approach according to claim 1 currently formed of $\text{Al}_x\text{Ga}_y\text{In}_{1-x-y}\text{P}$ ($0 < x \leq 1$, $0 \leq y \leq 1$).

[Claim 9] Said compound semiconductor is the etching approach according to claim 8 currently formed on the off substrate.

[Claim 10] The etching approach which is the etching approach which carries out dry etching of a group III-V semiconductor or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies, and includes the 1st dry etching process which makes halogen ion density larger than a halogen radical consistency, and etches it, and the 2nd dry etching process which makes halogen ion density smaller than a halogen radical consistency, and is etched.

[Claim 11] The etching system equipped with the reaction chamber linked to the source of a radical beam, the source of an ion beam, and this source of a radical beam and this source of an ion beam, the sample susceptor prepared in this reaction chamber, and a load lock chamber.

[Claim 12] The process which grows at least one compound semiconductor layer epitaxially on a semi-conductor substrate, The process which forms the mask by which patterning was carried out on one compound semiconductor layer even if there is none of these **, The process which etches to one compound semiconductor layer using the etching approach according to claim 1 to 10 even if this ** cannot be found, and forms a ridge stripe using this mask, The manufacture approach of the semiconductor laser component which includes the process which embeds this ridge stripe with a compound semiconductor.

[Claim 13] It is the manufacture approach of a semiconductor laser component given in the claim 12 in which said

substrate is an inclination substrate, said at least one compound semiconductor layer contains in the barrier layer, and the n mold AlGaInP cladding layer and p mold AlGaInP cladding layer which sandwich this barrier layer, and said ridge stripe contains this p mold AlGaInP layer.

[Claim 14] Said p mold AlGaInP cladding layer is the manufacture approach of a semiconductor laser component according to claim 13 that have the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP, and the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.

[Claim 15] The manufacture approach of a semiconductor laser component according to claim 14 that the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.

[Claim 16] The include angle which it is prepared on the substrate and this substrate, and it is the semiconductor laser component equipped with the ridge stripe containing a barrier layer, and n mold cladding layer which sandwiches this barrier layer and p mold cladding layer, and this ridge stripe has the laser section which carries out laser oscillation, and a taper-like point, and is made with the base of this ridge stripe and the side face of this ridge stripe is an about 60-degree or more semiconductor laser component which is 90 degrees or less.

[Claim 17] It is the semiconductor laser component by which is been the semiconductor laser component equipped with the inclination substrate, and the n mold AlGaInP cladding layer formed on this substrate, a barrier layer and a p mold AlGaInP cladding layer, and this p mold AlGaInP cladding layer has ridge structure with an almost symmetrical configuration, and the current block layer is formed in the both sides of this ridge structure.

[Claim 18] Said p mold AlGaInP cladding layer is a semiconductor laser component according to claim 17 which has the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP and by which the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.

[Claim 19] The semiconductor laser component according to claim 18 by which the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.

[Claim 20] This width of face that has the width of face to which said point becomes narrower to the shape of a taper than the width of face of said laser section is a semiconductor laser component according to claim 16 which is about 1 micrometer or less.

[Claim 21] Said point is a semiconductor laser component according to claim 16 which has the width of face which becomes larger to the shape of a taper than the width of face of said laser section.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the dry etching approach of a compound semiconductor especially an III-V group, or an II-VI group compound semiconductor, and the semiconductor laser component produced using it.

[0002]

[Description of the Prior Art] There is an approach indicated by JP,7-66175,A as a dry etching technique of the conventional compound semiconductor. By this approach, dry etching is performed to In system compound semiconductor using compound magnetic field mold ECR-RIBE (electron cyclotron resonance-reactivity ion beam etching) equipment. With compound magnetic field mold ECR-RIBE equipment, it has the coil of two functions, a main coil and a subcoil, and emission of the magnetic field near [to etch] a sample is suppressed. According to this approach, chlorine and nitrogen are used as etching gas. A perpendicular cross section and a smooth etching side are acquired [the flow rate of chlorine gas / nitrogen gas] for internal pressure to an etching mask on condition that 0.5mTorr(s) or less to one.

[0003] According to the above-mentioned official report, in chlorine gas / nitrogen gas, when supplying gas at one or less rate, generating of a chlorine radical is controlled and etching by the chlorine ion serves as dominance from a chlorine radical. For this reason, even if it uses the ion which has about teneV low energy, the balance of evaporation of the chloride of In and the chloride of P can be maintained. Consequently, etching from which a perpendicular cross section and a smooth etching side are acquired to an etching mask is realizable.

[0004]

[Problem(s) to be Solved by the Invention] Conventionally, in the dry etching of a compound semiconductor, problems, such as difficulty, had the dry area of the etching side resulting from the difference of the vapor pressure of the reactant of an III group element and etching gas and vapor pressure with the reactant of V group element and etching gas being large, and control of a cross-section configuration.

[0005] The dry etching technique indicated by above-mentioned JP,7-66175,A is also for solving this problem. With this technique, by addition of nitrogen gas, chlorine gas decomposes and the amount of generation of a chlorine radical is controlled by about 1/3 among the chlorine ion generated and the chlorine radical. The above-mentioned problem is solved by this. Moreover, with the above-mentioned technique, in order to make the amount of generation of a chlorine radical into min, the pressure in a reaction chamber is set to 0.5 or less mTorr. Consequently, the desorption rate of the chloride of In and the chloride of P is balanced. The description of the above-mentioned technique is etching on the conditions from which chlorine radical concentration's becomes min. The above-mentioned official report does not show the quantitative data about the amount of generation and etching property of a chlorine ion.

[0006] Moreover, when aluminum is contained in the sample to etch, there is a problem to which it is no longer etched into or an etching rate falls greatly by aluminum 2O3 being formed of the residual moisture in a reaction chamber.

[0007] The place which this invention is made in view of the above-mentioned situation, and is made into the purpose As opposed to an III-V group and an II-VI group compound semiconductor, and the group III-V semiconductor that contains aluminum further Without reducing the amount of chlorine gas radical formation using the chlorine gas which added nitrogen gas It is in offering the semiconductor laser component which offered the dry etching approach by which a perpendicular cross section and a smooth etching side are acquired, and was produced using this dry etching approach, and its manufacture approach.

[0008]

[Means for Solving the Problem] The etching approach by this invention with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies It is the etching

approach which carries out dry etching of a group III-V semiconductor or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen. It is (the flow rate of the gas containing a halogen) / (flow rate of nitrogen gas) about ≥ 1 , and the pressure under etching reaction is about 1 mTorr or 1 or more mTorr, and the above-mentioned purpose is attained by that.

[0009] With a certain operation gestalt, the 1st etching process which performs the above-mentioned dry etching, and the 2nd etching process which performs wet etching are included.

[0010] With a certain operation gestalt, the ion generated in said source of the plasma is accelerated, and it etches with the kinetic energy of this accelerated ion, heating a sample front face.

[0011] With a certain operation gestalt, the ion generated in said source of the plasma is accelerated, with the kinetic energy of this accelerated ion, it heats only near the front face of the sample containing an II-VI group compound, and the susceptor of this sample is cooled.

[0012] It etches with a certain operation gestalt, heating sample susceptor.

[0013] the 1st dry etching process which accelerates with the 1st acceleration voltage and etches the ion generated in said source of the plasma with a certain operation gestalt -- this -- it carries out after the 1st dry etching process, and the ion generated in this source of the plasma is accelerated with the 2nd acceleration voltage, the 2nd dry etching process to etch is included further, and this 1st acceleration voltage is larger than this 2nd acceleration voltage.

[0014] With a certain operation gestalt, said dry etching system is equipped with the source of a radical beam, and the source of an ion beam, and it performs dry etching, controlling independently the consistency of the radical generated by this source of a radical beam, and the consistency of the ion generated by this source of an ion beam, respectively.

[0015] With a certain operation gestalt, said compound semiconductor is formed of $\text{Al}_x\text{Ga}_{1-x}\text{In}_y\text{P}$ ($0 < x \leq 1$, $0 \leq y \leq 1$).

[0016] With a certain operation gestalt, said compound semiconductor is formed on the off substrate.

[0017] Other etching approaches by this invention with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies It is the etching approach which carries out dry etching of a group III-V semiconductor or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen. The 1st dry etching process which makes halogen ion density larger than a halogen radical consistency, and etches it, Halogen ion density is made smaller than a halogen radical consistency, the 2nd dry etching process to etch is included and the above-mentioned purpose is attained by that.

[0018] The etching system by this invention is equipped with the reaction chamber linked to the source of a radical beam, the source of an ion beam, and this source of a radical beam and this source of an ion beam, the sample susceptor prepared in this reaction chamber, and a load lock chamber, and the above-mentioned purpose is attained by that.

[0019] The manufacture approach of the semiconductor laser component by this invention The process which grows at least one compound semiconductor layer epitaxially on a semi-conductor substrate, The process which forms the mask by which patterning was carried out on one compound semiconductor layer even if there is none of these **, The process which etches to one compound semiconductor layer using the etching approach according to claim 1 to 10 even if this ** cannot be found, and forms a ridge stripe using this mask, The process which embeds this ridge stripe with a compound semiconductor is included, and the above-mentioned purpose is attained by that.

[0020] With a certain operation gestalt, said substrate is an inclination substrate, said at least one compound semiconductor layer contains the barrier layer, and the n mold AlGaInP cladding layer and p mold AlGaInP cladding layer which sandwich this barrier layer, and said ridge stripe contains this p mold AlGaInP layer.

[0021] With a certain operation gestalt, said p mold AlGaInP cladding layer has the 1st cladding layer of p mold AlGaInP , and the 2nd cladding layer of p mold AlGaInP , and the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.

[0022] With a certain operation gestalt, the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP .

[0023] The semiconductor laser component by this invention is prepared on the substrate and this substrate. A barrier layer, It is the semiconductor laser component equipped with the ridge stripe containing n mold cladding layer which sandwiches this barrier layer, and p mold cladding layer. This ridge stripe It has the laser section which carries out laser oscillation, and a point, the base of this ridge stripe, the side face of this ridge stripe, and the include angle to make are about 60 degrees or more 90 degrees or less, and the above-mentioned purpose is attained by that.

[0024] With a certain operation gestalt, said point has the width of face which becomes thin in the shape of a taper from the width of face of said laser section, and this width of face is about 1 micrometer or less.

[0025] With a certain operation gestalt, said point has the width of face which becomes larger to the shape of a taper than the width of face of said laser section.

[0026] Other semiconductor laser components by this invention are semiconductor laser components equipped with the inclination substrate, and the n mold AlGaInP cladding layer formed on this substrate, a barrier layer and a p mold AlGaInP cladding layer, this p mold AlGaInP cladding layer has ridge structure with an almost symmetrical configuration, the current block layer is formed in the both sides of this ridge structure, and the above-mentioned purpose is attained by that.

[0027] With a certain operation gestalt, said p mold AlGaInP cladding layer has the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP, and the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.

[0028] With a certain operation gestalt, the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.

[0029]

[Embodiment of the Invention] Below, the operation gestalt of this invention is explained at a detail.

[0030] (1st operation gestalt) As 1st operation gestalt of the dry etching approach by this invention, the dry etching approach for a group III-V semiconductor is explained. InP is used as a sample to etch. Chlorine gas and nitrogen gas are used as etching gas. Drawing 1 shows the configuration of the ECR-RIBE equipment (it is called ECR-RIBE equipment for short electron cyclotron resonance-reactivity ion beam etching and the following) used with this operation gestalt in ** type. In this equipment, the location of the sample to etch is located on the outside of the coil which generates a magnetic field.

[0031] As shown in drawing 1, ECR-RIBE equipment is connected with ECR source 101 and the ECR source, and is mainly equipped with the reaction chamber 102 and exhaust air pump system (not shown) for installing a sample. Ion and a radical are generated in ECR source 101. From a gas inlet 108, the chlorine gas and the nitrogen gas by which the flow rate was controlled are introduced into ECR source 101. Furthermore, 2.45GHz microwave will face the quartz aperture 107, and will be introduced into ECR source 101, and chlorine gas and nitrogen gas will be from a waveguide 106 in an excitation state. An electron sympathizes with the 875 gauss magnetic field generated with the coil 103, and it repeats gas and a collision, carrying out the circular motion. In this way, it is accelerated by the grid 104 and the chlorine ion and nitrogen ion which were generated in ECR source 101 are irradiated by the sample 105.

[0032] Although it is accelerated and a chlorine ion and nitrogen ion are irradiated by the sample 105, since it is not ionized, the chlorine radical and nitrogen radical which are generated in ECR source 101 are not accelerated. However, a chlorine radical and a nitrogen radical arrive at the front face of a sample 105 by diffusion, and contribute to etching. As for this ECR-RIBE equipment, unlike the compound magnetic field mold, the coil is not installed in the side face of a reaction chamber 102. For this reason, the magnetic field generated with a coil 103 is an emission magnetic field.

[0033] The ion and radical which were produced as mentioned above arrive at sample 105 front face, react with InP which is a sample, and In chloride and P chloride generate them. The boiling point of PCl_3 has the boiling point of 76 degrees C and PCl_5 as low as 162 degrees C, and evaporates P chloride easily.

[0034] On the other hand, the boiling point of 560 degrees C and InCl_3 has the boiling point of 608 degrees C and InCl_2 as high as 600 degrees C, and the boiling point of InCl cannot evaporate In chloride easily. For this reason, the layer of In chloride is formed in the front face of a sample 105. Since evaporation of In chloride is promoted, the acceleration voltage of ion serves as an important element, because the chlorine ion and nitrogen ion which were accelerated collide with the front face of a sample 105 from ECR source 101. Less than [acceleration voltage 300V], evaporation does not take place and In chloride is not etched.

[0035] Table 1 shows the conditions of etching of being used with this operation gestalt.

[0036]

[Table 1]

塩素	窒素	マイクロ波パワー	加速電圧	内圧	試料温度
3~20 SCCM	3.5~35 SCCM	200W(固定)	300~900 V	0.5~2.5 mTorr	室温 -300℃

[0037] In the conditions shown in Table 1, acceleration voltage is about 300v or more, and etching is the optimal. In addition, SiO_2 is used as a mask for etching.

[0038] The main results of having performed dry etching to below using the conditions shown in Table 1 are explained.

[0039] In the experiment, the chlorine flow rate was set as about 10 SCCM(s), about 2.5 mTorr(s) and sample temperature were set [acceleration voltage] as about 200 degrees C for the internal pressure under about 650V and reaction, the nitrogen flow rate was changed, and dry etching was performed. Evaporation of an III group compound can

be promoted by heating sample susceptor and maintaining sample temperature at about 200 degrees C.

[0040] As a nitrogen flow rate, drawing 2 shows each cross-section photograph of InP to which about 35 SCCM(s) and drawing 3 performed about 7 SCCM(s) on condition that about 3.5 SCCM(s), and drawing 4 performed dry etching in a mimetic diagram.

[0041] Drawing 2 (a) shows the cross section etched using SiO₂ mask to an InP substrate. Although InP is etched as shown in this drawing, the base (etching side) is very ruined. Drawing 2 (b) is the perspective view of drawing 2 (a). Drawing 2 (b) also shows well that the base is ruined. In the case of drawing 3, etching is possible in the almost perpendicular direction to SiO₂ mask, and most base dry areas are lost. In the case of drawing 4, there is no base dry area and the etching side is smooth. However, side etching into which the mask bottom is also etched takes place, and perpendicular etching has not been performed to the mask.

[0042] The above-mentioned result shows that there is a boundary where the etching side of nitrogen flow rate [a chlorine flow rate /] is ruined between about 0.29 and 1.43. According to the experiment, it turned out that the ratios of the chlorine flow rate / nitrogen flow rate of the boundary are the about 1.0 neighborhoods. Moreover, it turns out that the smooth nature of an etching side has [the about 2.85 neighborhoods] the best ratio of a chlorine flow rate / nitrogen flow rate.

[0043] However, if the cross-section configuration of drawing 4 is seen, it is not perpendicular and side etching is considerably contained. In order to obtain a perpendicular cross section, it is necessary to stop the chemical reaction component in dry etching. Then, it etched by lowering sample temperature to about 100 degrees C. The result is shown in drawing 5 (conditions other than temperature are the same as the case of drawing 4). [0044] By lowering sample temperature to 100 degrees C, a spatter component will become strong from chemical reactivity, and SiO₂ mask will retreat by being etched (it moves to a substrate side). For this reason, over etching happens and it becomes a trapezoid cross-section configuration. However, since the etching side is very smooth, it is satisfactory practically also in a trapezoid cross section.

[0045] As shown in drawing 4 and 5, when the chemical reaction component in etching is more superior than a spatter component, side etch happens, when a spatter component is more superior than chemical reactivity, a mask retreats and over-etching happens.

[0046] Next, examination of the etching conditions for obtaining a perpendicular cross section is explained.

[0047] In order to make chemical reactivity increase, sample temperature was made into about 150 degrees C, in order to raise an etching rate, the amount of supply of chlorine was increased up to about 11.5 SCCM(s) (a nitrogen flow rate is 3.5SCCM(s) as well as the case of drawing 4), and it etched. The result is shown in drawing 6. A spatter component and a chemical reaction component can be balanced and a perpendicular etching cross section is realized so that drawing 6 may show. In this case, acceleration voltage is about 650V and internal pressure is still about 2.5 mTorr(s).

[0048] Each etching condition in drawing 2 -6 is collectively shown in Table 2.

[0049]

[Table 2]

	塩素 (SCCM)	窒素 (SCCM)	塩素／窒素 流量比	加速電圧 (V)	内圧 (mTorr)	試料温度 (℃)
図2	10	35	0.29	650	2.5	200
図3	10	7	1.43	650	2.5	200
図4	10	3.5	2.8	650	2.5	200
図5	10	3.5	2.8	650	2.5	100
図6	11.5	3.5	3.29	650	2.5	150

[0050] It will not be ruined if the ratio of a chlorine flow rate / nitrogen flow rate is about 1.0 or more. However, if this flow rate is made large to 6.4 or more, it will begin to be ruined for a while again. In consideration of the dry area of an etching side, the range of the optimum value of the flow rate of a chlorine flow rate / nitrogen flow rate is about 1.0 to 6.4.

[0051] drawing 16 -- the spectrum of plasma luminescence -- a result is shown. An optical result expresses a change of the nitrogen ion and chlorine ion to nitrogen concentration, and a chlorine radical on the strength at this rate. Each luminescence reinforcement shown in drawing 16 is standardized by the plasma luminescence reinforcement of only chlorine gas. As for nitrogen ion, 652.9nm was observed, and, as for the chlorine ion, luminescence by 727.9nm was observed, as for 450.8nm and a chlorine radical. Luminescence by 652.9nm only in the case of chlorine gas is a noise,

and is not luminescence by nitrogen ion.

[0052] The luminescence reinforcement of nitrogen ion increases simply in proportion to the addition of nitrogen. Although the luminescence reinforcement by the chlorine ion increases by addition of nitrogen, the addition concentration of nitrogen shows maximum at about 23%. This maximum is about 1.4 times in nitrogen additive-free. Then, according to the increment in nitrogen addition concentration, slight luminescence reinforcement by the chlorine ion decreases, and is saturated with one about 1.3 times [in nitrogen additive-free] the value of this. although it increases about 10% by addition of nitrogen, it comes out to this extent and the luminescence reinforcement by the chlorine radical is saturated, and even if it adds nitrogen further, it does not increase.

[0053] Below, change of the above-mentioned luminescence reinforcement is explained as compared with an etching property.

[0054] When a chlorine flow rate / nitrogen flow rate is less than one, the nitrogen concentration in drawing 16 is a field (field **) exceeding 50%. In field **, although chlorine ion reinforcement is about 1.3 or more times to the case of pure chlorine (nitrogen additive-free), nitrogen ionic strength has increased about 3 times. That is, it is thought with superfluous nitrogen ion by carrying out the spatter of the P chloride with vapor pressure high among In chloride and P chloride alternatively that it is ruined.

[0055] When a chlorine flow rate / nitrogen flow rate is 6.4 or less [about 1 or more], the nitrogen concentration of drawing 16 is equivalent to about 50% or less of field (field **) about 13% or more. In this field, the reinforcement of nitrogen ion does not increase so much, but balance of the desorption from the front face of In chloride and P chloride can be taken, and the smooth etching side is realized.

[0056] When a chlorine flow rate / nitrogen flow rate exceeds 6.4, the nitrogen concentration of drawing 16 is equivalent to about 13% or less of field (field **). In field **, it is ruined again. Since the desorption of In chloride which this generated, and P chloride mainly happens with heat energy from the spatter effectiveness, it is thought that it is because the alternative desorption of P chloride happens.

[0057] As stated above, the effectiveness which adds nitrogen gas not only promotes generation of a chlorine ion, but in this invention, the big description has it in the place which promotes the desorption of the chloride of an III group or V group according to the spatter effectiveness by the nitrogen ion itself. This is also the same as when this invention is applied to an II-VI group compound semiconductor.

[0058] In the above explanation, as an ingredient to etch, although a group's III-V semiconductor InP was used, the ingredient of an AlGaInP system, an AlGaInN system, and the ZnMgSSe system of an II-VI group compound semiconductor may be used instead of InP so that it may explain later. Moreover, although an etching rate falls, etching is possible even if it holds substrate temperature to a room temperature.

[0059] (2nd operation gestalt) Below, the dry etching approach for a group III-V semiconductor is explained as 2nd operation gestalt of the dry etching approach by this invention. More specifically, the dry etching approach to etch is explained with the kinetic energy of the accelerated ion, heating only a sample front face, without raising the temperature of the whole sample.

[0060] InP is used as an etching sample and SiO₂ is used as an etching mask. In addition, the approach of this operation gestalt is applicable to etching of an II-VI group compound semiconductor.

[0061] As the operation gestalt of the above 1st described, when raising sample temperature, the chemical reaction component in dry etching becomes dominance from a spatter component, and side etching into which the mask bottom is also etched takes place. However, if sample temperature is lowered, since a spatter component will become strong, over-etching to which a mask retreats is caused, or an etching base is ruined.

[0062] So, with this operation gestalt, it is made to stick to the sample maintenance fixture which produced the sample with aluminum, and it etches, cooling this maintenance fixture.

[0063] By the grid, it is accelerated by hundreds V and the ion generated in an ECR source is irradiated by the sample with kinetic energy. The radical generated in an ECR source is not accelerated. Since the energy per radical has many radicals generated with 20-30eV although it is small, the total energy received from a radical has a quite large sample front face. Thus, in order that a sample front face may obtain many ion and the energy of a radical, even if it does not go up the temperature of a sample substrate, the same effectiveness as the case where the sample itself is raised to hundreds of degrees C is acquired. That is, by heating the front face of a sample in this way, evaporation of the chloride of an III group or II group is promoted, and an etching rate is improved.

[0064] ECR-RIBE equipment is used, about 200W and internal pressure are set to about 2.5 mTorr(s), it sets [a chlorine flow rate / about 11.5 SCCM(s) and a nitrogen flow rate] acceleration voltage to about 650 V for about 3.5 SCCM(s) and microwave power, and drawing 8 shows the cross section of InP at the time of performing dry etching to InP.

[0065] In this case, it is not heating to the whole sample. The sample maintenance fixture produced with aluminum is

equipped with the sample. A sample maintenance fixture is put on the sample susceptor by which water cooling was carried out. Only the part near the front face of a sample is heated by this, and the temperature of the part except this part does not rise by it. A sample is protected from a thermal damage. Especially the thing done like this is effective in etching the sample containing an II-VI group compound. Because, since the crystal growth temperature (about 260 degrees C) of an II-VI group compound semiconductor is low, in order to prevent crystalline degradation, it is necessary to make etching temperature lower (about 250 degrees C or less) than crystal growth temperature.

[0066] As the operation gestalt of the above 1st described, the configuration of an etching cross section reflects the balance of the spatter component to etch and a chemical reaction component. That is, when a spatter component is dominance, over-etching of the cross section is carried out, and when a chemical reaction component is dominance, side etching takes place.

[0067] Although the temperature of the whole sample is near a room temperature according to this operation gestalt as drawing 8 shows, the cross section is almost perpendicular and has balanced the chemical reaction component and the spatter component. The cross section of drawing 8 shows the same cross-section configuration as the case of drawing 6, when it etches by setting sample temperature as 150 degrees C. That is, the result shown in drawing 8 which etched without heating is the same as the result shown in drawing 6 which etched by setting sample temperature as 150 degrees C about the cross-section configuration. However, the etching rate in the case of drawing 8 is lower than it in the case of drawing 6 25%.

[0068] In addition, with this operation gestalt, although sample temperature is set up near the room temperature, it can also make the difference [chloride / of an III group] of sublimation small by cooling sample susceptor at 0 degree C or less, and controlling sublimation of V group's chloride. This can perform dry etching from which a perpendicular cross section and a smooth etching side are acquired.

[0069] (3rd operation gestalt) As 3rd operation gestalt of the dry etching approach by this invention, the dry etching approach for a group III-V semiconductor is explained. The dry etching approach of more specifically performing two steps of etching of different conditions is explained. As a sample, SiO₂ is used as InP and an etching mask, and chlorine and nitrogen are used as etching gas.

[0070] The 1st dry etching is first performed using ECR-RIBE equipment. In this 1st dry etching, by setting internal pressure to about 1 or less mTorr, and setting acceleration voltage to about 300v or more, the collision between gas molecules is suppressed and ion density is made larger than a radical consistency. About 1 or more and sample temperature are set as about 100 degrees C for a chlorine flow rate / nitrogen flow rate. In this case, etching by the spatter component becomes dominance from a chemical reaction component, the high-speed dry etching in a perpendicular direction progresses to a sample front face, and the configuration near a desired configuration is formed.

[0071] The 1st dry etching of the above has the above and a comparatively high etching rate by about 1000A/. When etching at high speed, in the etched side face or etching side, the damage by which induction is carried out to processing arises, or it is ruined. This is because a crystal defect arises in a sample, when it is accelerated on the high electrical potential difference beyond 300V and the halogen ion generated in an ECR source is irradiated by the sample. Moreover, since the boiling points of a halogenide differ to an III group (or II group) and V groups (or VI group), when the stoichiometry in an etching side shifts, it is because the III group (or II group) elements in an etching side increase in number more than V group (or VI group) element in an excess.

[0072] Next, it continues at the 1st dry etching and the 2nd dry etching is performed. It is removing the layer which has the processing induction damage produced by the 1st dry etching as a purpose which performs this 2nd dry etching. Moreover, it is removing the devastated field and making it smooth by the 1st dry etching, when a dry area's arises in an etching side. In order to attain the above-mentioned purpose, about 3 or more and internal pressure are set as about 2 or more mTorr, it sets about 300v or less and sample temperature as about 200 degrees C for acceleration voltage, and the 2nd dry etching performs a chlorine flow rate / nitrogen flow rate. In this case, the collision between gas molecules increases and the radical consistency becomes large from ion density. Furthermore, since a mean free path becomes small, the chemical reaction component acts strongly from a spatter component.

[0073] Since the processing induction damage done to a crystal is small, etching under the strong conditions of the above chemical reactivity can remove a layer including many processing induction damages produced in the 1st dry etching. When ruined in the 1st dry etching, the devastated field can be made smoother by the 2nd dry etching of the above.

[0074] The 1st dry etching is a chlorine flow rate. Although it can carry out on condition that /nitrogen flow rate abbreviation ≥ 1 , internal pressure abbreviation ≤ 1 mTorr, and acceleration voltage abbreviation ≥ 300 V, a chlorine flow rate / nitrogen flow rate abbreviation ≥ 3 , internal pressure abbreviation ≤ 0.5 mTorr, and acceleration voltage abbreviation ≥ 600 V are more more desirable as optimum conditions.

[0075] Although the 2nd dry etching can be performed on condition that a chlorine flow rate / nitrogen flow rate

abbreviation ≥ 3 , internal pressure abbreviation ≥ 2 mTorr, and acceleration voltage abbreviation ≤ 300 V, a chlorine flow rate / nitrogen flow rate abbreviation ≥ 10 , internal pressure abbreviation ≥ 3 mTorr, and acceleration voltage abbreviation ≤ 100 V are more more desirable as optimum conditions.

[0076] Drawing 12 is the sectional view showing the process of the dry etching by this operation gestalt. First, as shown in drawing 12 (a), SiO₂ mask 1202 by which patterning was carried out is formed on the InP substrate 1201. Then, as shown in drawing 12 (b), the 1st dry etching is performed. According to this process, the damage layer 1203 by which induction is carried out to processing arises on an etching front face. Next, as shown in drawing 12 (c), the 2nd dry etching is performed. In the 2nd dry etching, a chlorine ion consistency is small and a chlorine radical consistency is larger than the case of the 1st dry etching. By performing the 2nd dry etching, the damage layer 1203 by which induction is carried out to processing is removed, and a perpendicular side face and a smooth etching side can be formed to a mask 1202.

[0077] In addition, in the above explanation, the size relation of the chlorine ion consistency and chlorine radical consistency in the 1st and 2nd dry etching was changed by changing internal pressure, flow rate, and acceleration voltage. Instead, the 1st and the 2nd dry etching may be performed by changing only acceleration voltage. That is, the 1st and 2nd dry etching is a chlorine flow rate. Using conditions with /nitrogen flow rate abbreviation ≥ 3 , an internal pressure abbreviation ≥ 2 mTorr, and a sample temperature of about 200 degrees C, in the 1st dry etching, acceleration voltage is set as about 900 V, and acceleration voltage is set as about 100 V by the 2nd dry etching. On such conditions, even if it performs dry etching, etching without a dry area is realizable.

[0078] (4th operation gestalt) Below, the etching approach for a group III-V semiconductor is explained as 4th operation gestalt of the etching approach by this invention. More specifically, the etching approach of performing two steps of etching, dry etching and wet etching, is explained. As a sample, SiO₂ is used as InP and an etching mask, and chlorine and nitrogen are used as etching gas. As an etching solution of wet etching, a hydrochloric acid, an acetic acid, and hydrogen peroxide solution are used.

[0079] First, 1st etching (dry etching) is performed using ECR-RIBE equipment. In this 1st etching, abbreviation ≥ 1 and internal pressure are made to about 2 or more mTorr, and about 300 v or more and sample temperature are made [a chlorine flow rate / nitrogen flow rate] into about 100 degrees C or more for acceleration voltage. Although the 1st etching is possible on the above-mentioned conditions, for about 3.5 SCCM(s) and sample temperature, about 150 degrees C and acceleration voltage are [a chlorine flow rate / about 11.5 SCCM(s) and a nitrogen flow rate / about 650 V and internal pressure of optimum conditions] about 2.5 mTorr(s). On such conditions, a sample is processible into a predetermined configuration. A layer including the processing induction damage generated by the 1st etching is removed by the 2nd etching explained below.

[0080] Drawing 7 shows typically the configuration of the spin etching system used for the 2nd etching. 2nd etching, i.e., wet etching, is performed in a reaction chamber 705. The sample 701 by which dry etching was carried out [above-mentioned] is installed on the sample maintenance base 702. The sample maintenance base 702 holds a sample 701 by the vacuum chuck, and rotates with a predetermined rotational speed. The mixed liquor of the hydrochloric acid which is maintained by the etchant tank 704 and saved to predetermined temperature at it, an acetic acid, and hydrogen peroxide solution comes out of a nozzle 703, and flows and falls on a sample 701. The core of a nozzle 703 and the sample maintenance base 702 is in agreement, and a nozzle 703 reciprocates the between to a predetermined distance to radial [of the core of the sample maintenance base 702 to a sample maintenance base]. While a nozzle 703 fails to flow liquid in the sample 701 to rotate, very uniform wet etching is performed by reciprocating radial. In this way, the damage layer by which induction is carried out to processing produced by the 1st etching is removed. The temperature of 3:36:1 and mixed liquor of the mixing ratio of a hydrochloric acid, an acetic acid, and hydrogen peroxide solution should just be 20 degrees C.

[0081] Since wet etching does not contain a spatter component, some damages which are given by using dry etching can also be prevented by using wet etching. For this reason, the smooth nature of an etching side can be improved further.

[0082] In this operation gestalt, as a solution used for the 2nd etching, although a hydrochloric acid, an acetic acid, and hydrogen peroxide solution were used, it may replace with this and the mixed liquor of the mixed liquor of the mixed liquor of a sulfuric acid, hydrogen peroxide solution, and water, a hydrochloric acid, and a phosphoric acid or saturation bromine water, and a methanol may be used. What is necessary is just the solution from which induction is carried out to processing produced by the 1st etching in short, and a damage layer can be removed.

[0083] (5th operation gestalt) The dry etching system which equipped below with the source of a radical beam and the source of an ion beam other than an ECR source, and the dry etching approach using it are explained.

[0084] Drawing 9 shows typically the configuration of the dry etching system of this operation gestalt. This equipment is equipped with the source 902 of a radical beam and the source 903 of an ion beam other than ECR source 904 and a

reaction chamber 901. The source 902 of a radical beam and the source 903 of an ion beam are connected to the reaction chamber 901.

[0085] All over the reaction chamber 901, it has the sample maintenance base 905 holding a sample 906. The chlorine ion generated by the chlorine radical generated in the source 902 of a radical beam, the chlorine ion generated in the source 903 of an ion beam, and ECR source 904, a chlorine radical, and nitrogen ion are irradiated by the sample 906. A sample 906 is sent to a reaction chamber 901 from the load lock chamber 900 for paying a sample 906 to a reaction chamber 901. A reaction chamber 901 is exhausted by about 10 to 6 or less Torrs by the exhaust air system (not shown).

[0086] In the source 902 of a radical beam, RF RF will be added and chlorine gas will be in the plasma state. A chlorine ion and a chlorine radical occur by this. Since a mean free path is several centimeters, it collides with other atoms or an electron and a chlorine ion disappears in the source 902 of a radical, or a reaction chamber 901 when not accelerated, it does not reach to a sample. The generated radical arrives even at a sample front face by diffusion, and contributes to a reaction.

[0087] On the other hand, also in the source 903 of an ion beam, RF RF will be added and chlorine gas will be in the plasma state. A chlorine ion and a chlorine radical occur by this. By changing the electrical potential difference applied to the drawer electrode 9031, by changing the rate of the chlorine ion pulled out from the source 903 of an ion beam, and a chlorine radical, many chlorine ions are pulled out and irradiated on a sample front face from a chlorine radical.

[0088] In ECR source 904, as the 1st operation gestalt described, gas is decomposed and ion and a radical are generated. Nitrogen gas is introduced into ECR source 904 in this operation gestalt.

[0089] The consistency of the radical which contributes to the smooth nature of the gas which contributes to a reaction, and the consistency of the ion contributed to an etching rate are independently controllable, respectively by having the ion source, a source of a radical, and an ECR source as mentioned above. For this reason, high-speed etching is possible, with the smooth nature of an etching side maintained. It becomes easy to control the smooth nature of an etching rate, a cross-section configuration, and an etching side. As the 1st operation gestalt described in the case of the dry etching of InP by the mixed gas of chlorine and nitrogen, using SiO₂ as a mask, P chloride is sublimated easily, and since it is hard to sublimate In chloride, the layer of In chloride will be formed in a sample front face. What is necessary is just to use the kinetic energy of the accelerated chlorine ion and nitrogen ion, in order to make the layer of this In chloride sublimate.

[0090] Then, what is necessary is to make [more] a chlorine ion flow rate than a chlorine radical flow rate, to accelerate by the high voltage of about 300v or more, and just to supply a chlorine ion and nitrogen ion. What is necessary is just to set sample temperature as about 150 degrees C or more, in order to make an etching rate high.

[0091] According to this operation gestalt, the dry etching of InP in which about 300v or more and the nitrogen ion from an ECR source are [about 10 or more SCCMs and acceleration voltage] about 3 or less SCCMs for the chlorine ion flow rate from about 1 or more SCCMs and the source of an ion beam, and the chlorine radical flow rate from the source of a radical beam has a smooth etching side is possible. Furthermore, dry etching in which a chlorine radical flow rate has the cross section about 1 SCCM and a chlorine ion flow rate has [the acceleration voltage of about 10 SCCM(s) and a chlorine ion / about 600v or more and the nitrogen flow rate of an ECR source] about 3 SCCM(s) and sample temperature perpendicular in a cross section on the conditions which are about 150 degrees C, and a smooth etching side is realized.

[0092] (6th operation gestalt) Below, the manufacture approach of a semiconductor laser component is explained using the etching approach explained with the operation gestalt of the above 1-5ths. The diameter conversion laser of a spot is used as a semiconductor laser component. Drawing 10 (a) - (c) shows typically the cross section of the structure of the diameter conversion laser of a spot.

[0093] This diameter conversion laser of a spot has the laser section 1010 and the spot-size transducer (point) 1011, as shown in drawing 10 (a). The laser section 1010 has the stripe configuration which has fixed width of face and thickness. As for the spot-size transducer 1011, width of face is [width of face] small toward the outgoing radiation edge 1012 at the shape of a taper. A laser beam is changed into the path m of the outgoing radiation edge (tip of a point 1011) 1012 of the spot-size transducer 1011 from the diameter of a spot in the laser section 1010, while guiding the spot-size transducer 1011. Width of face m is [the include angle of about 1 micrometer or less (typically about 0.6 micrometers) and a cross section of the outgoing radiation edge 1012] about 90 degrees.

[0094] Drawing 10 (b) shows the cross section in alignment with line A-A' of drawing 10 (a). As shown in drawing 10 (b), epitaxial growth of the n-InP layer 1002, the n-InGaAsP cladding layer 1003, a barrier layer 1004, the p-InGaAsP cladding layer 1005, and the p-InP cap layer 1007 is carried out one by one on the n-InP substrate 1001. these layers -- the mesa stripe (ridge stripe) 1014 -- constituting -- the mesa stripe 1014 -- half--- it is embedded by insulating InP1006. The p lateral electrode 1009 is formed on the p-InP cap layer 1007, and the n lateral electrode 1008 is formed all over the rear face of a substrate 1001.

[0095] The electron hole poured in from the p lateral electrode 1009 is recombined by the electron and barrier layer 1004 which were poured in from the n lateral electrode 1008. Luminescence takes place under the p lateral electrode 1009, and carries out laser oscillation by being shut up in a resonator end face.

[0096] Drawing 10 (c) shows the cross section in alignment with line B-B' of drawing 10 (a). The laser section 1010 differs in the width of face of a barrier layer 1004 from the spot-size transducer 1011 so that drawing 10 (b) and drawing 10 (c) may be compared and understood. That is, the direction of the width of face of the barrier layer 1004 of the spot-size transducer 1011 is small.

[0097] Below, the manufacture approach of the diameter conversion laser of a spot is shown, referring to drawing 11 (a) - (g). Drawing 11 (a) - (g) is the mimetic diagram of the cross section of the laser section 1010. The width of face of a barrier layer etc. only differs, and the spot-size transducer 1011 is manufactured by the laser section 1010 and coincidence.

[0098] First, as shown in drawing 11 (a), sequential growth of the n-InP layer 1102, the n-InGaAsP cladding layer 1103, a barrier layer 1104, and the p-InGaAsP cladding layer 1105 is carried out on the n-InP substrate 1101 by metal-organic chemical vapor deposition (MOVPE law). Then, as shown in drawing 11 (b), SiO₂ mask 1106 which has a predetermined configuration is formed on the p-InGaAsP cladding layer 1105.

[0099] Next, as shown in drawing 11 (c), the mesa stripe (ridge stripe) 1109 is formed using ECR-RIBE equipment by the etching approach explained with the operation gestalt of the above 1-5ths. Chlorine flow rate / nitrogen flow rate abbreviation ≥ 1 , and microwave power about 200W, the internal pressure of about 2 or more mTorr, the sample temperature of about 150 degrees C or more, and the acceleration voltage of the conditions of etching are about 300v or more. The side face of a mesa stripe and the front face of a substrate 1101 which are formed on this condition, and the include angle theta to make are about 60 degrees or more 90 degrees or less, as shown in drawing 11 (c) and (g). next, it is shown in drawing 11 (d) -- as -- MOVPE -- law -- SiO₂ mask 1106 -- as the mask of selective growth -- using -- crystal growth -- carrying out -- the mesa stripe 1109 -- half--- it embeds by insulating InP1107. after removing SiO₂ mask 1106, it is shown in drawing 11 (e) -- as -- MOVPE -- the p-InGaAsP cap layer 1108 is grown up by law. Finally, as shown in drawing 11 (f), it heat-treats by vapor-depositing the p lateral electrode 1111 and the n lateral electrode 1110, and ohmic contact is formed.

[0100] As explained above, according to this invention, a cavity and waveguide with the front face of the substrate 1101 as shown in drawing 11 (g), the side attachment wall of the mesa stripe whose include angle theta to make is about 60 degrees - 90 degrees, and outgoing radiation opening of 1 micrometer or less of **** can be formed by etching with ECR-RIBE equipment using chlorine gas and nitrogen gas. According to the approach of this invention, it is avoidable that the reverse mesa (the above-mentioned include angle theta is 90 degrees or more) to which the dependability of a component is fallen is formed.

[0101] In addition, in the above-mentioned explanation, although the width of face of a point 1011 is narrower to the shape of a taper than the width of face of the laser section 1010, it may become larger to the shape of a taper than the width of face of the laser section 1010.

[0102] In the above operation gestalt, although ECR-RIBE equipment was used, it may replace with this and the dry etching system equipped with the source of the inductive-coupling mold plasma, the dry etching system equipped with the source of the Helicon mold plasma, or the dry etching system equipped with the source of the NLD mold plasma may be used.

[0103] Moreover, although the above operation gestalt explained using InP as a compound semiconductor, other III-V groups or II-VI group compound semiconductors may be used. In addition, in the above explanation, although chlorine gas was used, the gas containing chlorine, a bromine, or iodine may be used.

[0104] (7th operation gestalt) Below, the manufacture approach of other semiconductor laser components is explained using the etching approach explained with the operation gestalt of the above 1-5ths, referring to drawing 13 (a) - (d). In this operation gestalt, the compound semiconductor etched contains aluminum (aluminum).

[0105] first, it is shown in drawing 13 (a) -- as -- MOVPE -- on the n mold GaAs substrate 1301 by law A n mold GaAs buffer layer (un-illustrating), n mold Al_xGa_{1-x}In_{1-y}P (0 < x ≤ 1, 0 ≤ y ≤ 1, and the following) AlGaInP The cladding layer 1302 called for short, the multiplex quantum well barrier layer 1303 constituted by an AlGaInP barrier layer and the GaInP well layer, the 1st cladding layer 1304 of p mold AlGaInP, the GaInP etching stopper layer 1305 (thickness: about 5nm), Epitaxial growth of the 2nd cladding layer 1306 of p mold AlGaInP is carried out. The GaAs substrate 1301 is an off substrate which inclines in the [110] directions about 10 degrees from the field (100).

[0106] Next, in order to form a ridge, 4 micrometers of **** and SiO₂ mask 1307 with a thickness of about 0.5 micrometers by which patterning was carried out are formed on the p mold AlGaInP layer 1306.

[0107] Next, as shown in drawing 13 (b), a ridge 1313 is formed by using SiO₂ mask 1307 as an etching mask using the

dry etching approach explained by the above 1-5ths. As conditions for etching, a chlorine flow rate / nitrogen flow rate is set as about 3.1 by setting a chlorine flow rate to about 11 SCCM(s), and setting nitrogen to about 3.5 SCCM(s). In addition, acceleration voltage is [about 2.5 mTorr(s) and the sample temperature of about 650V and internal pressure] about 100 degrees C. The ridge 1313 of symmetrical trapezoidal shape is obtained by performing dry etching on such conditions.

[0108] Usually, by etching using an inclination substrate, as shown in drawing 14 (b), a ridge does not become the configuration of bilateral symmetry. Since the substrate inclines from a field (100), in the wet etching using the etching reagent of a sulfuric-acid system, the inclination of the side face in the pars basilaris ossis occipitalis of a ridge becomes loose, and a ridge serves as an unsymmetrical configuration. Consequently, impregnation of the carrier to a barrier layer and light close, eye ** becomes an ununiformity, and the transverse mode becomes unstable. This becomes remarkable when operating laser at an elevated temperature especially.

[0109] Moreover, in the semiconductor laser of an AlGaInP system, in order to short-wavelength-ize wavelength of a laser beam, whenever [tilt-angle] is enlarged increasingly. The asymmetry of a ridge becomes larger as whenever [tilt-angle] becomes large. As shown in drawing 14 (a), in spite of using an OFF substrate by performing dry etching on the above-mentioned conditions according to this operation gestalt, the ridge 1412 with a symmetrical configuration can be formed.

[0110] The dry etching for carrying out ridge formation is stopped in the etching stopper layer 1305, as shown in drawing 13 (b). The thickness of the 2nd cladding layer 1306 of p mold AlGaInP etched by dry etching is about 1.5 micrometers. As the 2nd operation gestalt explained such a thick layer, about 1.3 micrometers is first etched by the 1st dry etching with a strong spatter component, and the about 0.2-micrometer p molds AlGaInP remaining by the 2nd dry etching with a strong chemical reaction component are etched after that. If it carries out like this, the damage by etching will not be exerted on the layer below the etching stopper layer 1305.

[0111] Moreover, as the 3rd operation gestalt explained, the 2nd cladding layer 1306 with a thickness of about 1.3 micrometers may be etched by dry etching with a strong spatter component, and the 2nd about 0.2-micrometer remaining cladding layers 1306 may be etched by wet etching as the 2nd etching.

[0112] After forming a ridge 1313, as shown in drawing 13 (c), the n mold GaAs current block layer 1309 which is n mold embedding layer is grown up alternatively, using SiO₂ mask 1307 as it is.

[0113] Next, SiO₂ mask 1307 is removed, and as shown in drawing 13 (d), the p mold GaAs contact layer 1310 is grown up. Finally, the p lateral electrode 1312 is formed in the rear face of the n mold GaAs substrate 1301 on the n lateral electrode 1311 and the contact layer 1310, and laser structure is completed.

[0114] In the manufacture approach of the semiconductor laser component of this operation gestalt, by setting the flow rate of halogen gas and nitrogen gas as formation of a ridge 1313 in an abbreviation $1.4 \leq \text{chlorine flow rate} / \text{nitrogen flow rate} \leq \text{about } 4.0$ range Although the base of a ridge 1313, the side face of a ridge 1313, and the include angle theta to make use an OFF substrate while turning into about 60 - 90 degrees, they can manufacture a semiconductor laser component with a ridge configuration with sufficient symmetry. For this reason, the carrier to a barrier layer shuts up, light closes, and eye ** does not become an ununiformity, but a semiconductor laser component with high dependability with the stable transverse mode is obtained. Furthermore, according to this operation gestalt, an etching rate does not fall in spite of etching of the compound semiconductor containing aluminum. In addition, in the above explanation, in the process which carries out dry etching of the 2nd cladding layer of p mold AlGaInP, conditions are changed in the phase which etched about 1.3 micrometers of AlGaInP cladding layers by the 1st dry etching, and the 2nd dry etching is performed. Here, in order to detect easily (monitor), as it is shown in the part of this thickness of an AlGaInP cladding layer at drawing 15 (a) that the AlGaInP cladding layer with a thickness of about 1.3 micrometers was etched, the GaInP layer 1500 (thickness: about 10nm) from which the 2nd cladding layer 1506 of AlGaInP and a presentation differ may be inserted beforehand.

[0115] Since the GaInP layer 1500 does not contain aluminum when the 2nd cladding layer of AlGaInP is etched and etching advances by the GaInP layer 1500, carrying out spectrographic analysis from the plasma by forming the GaInP layer 1500, the value of spectrographic analysis changes. It is correctly detectable that about 1.3 micrometers of the 2nd cladding layer were etched with this change. And what is necessary is to perform the 2nd dry etching and just to etch that of the 2nd cladding layer of the remaining about 0.2-micrometer thickness, as etching conditions are changed and it is shown in drawing 15 (b). By carrying out like this, further, there are few damages at the time of etching, and its controllability is good, and they can manufacture the semiconductor laser component which has a uniform property.

[0116] The desorption of aluminum 2O₃ can be promoted by sputtering by increasing the amount of chlorine ion generation, without the amount of chlorine radical formation making it decrease, when aluminum is contained in the sample to etch according to this operation gestalt, even if aluminum 2O₃ is formed of the residual moisture in a reaction

chamber. Moreover, a chlorine radical and aluminum are made to react, and aluminum serves as an aluminum chloride and ****s. For this reason, the problem to which a sample is no longer etched into or an etching rate falls is avoidable.

[0117]

[Effect of the Invention] According to this invention, the following effectiveness is acquired.

[0118] Dry etching of the III-V group who has a smooth etching side, and an II-VI group compound semiconductor can be performed by holding about 1 or 1 or more, and internal pressure for a chlorine flow rate / nitrogen flow rate to about 1 mTorr or 1 or more mTorr.

[0119] Moreover, dry etching of the III-V group who has a smooth etching side, and an II-VI group compound semiconductor can be performed by controlling independently the amount of a chlorine ion consistency, a chlorine radical consistency, and nitrogen ion density, and performing dry etching using the dry etching system equipped with the source of a radical, and the source of an ion beam.

[Translation done.]

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TECHNICAL FIELD

[Field of the Invention] This invention relates to the dry etching approach of a compound semiconductor especially an III-V group, or an II-VI group compound semiconductor, and the semiconductor laser component produced using it.

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PRIOR ART

[Description of the Prior Art] There is an approach indicated by JP,7-66175,A as a dry etching technique of the conventional compound semiconductor. By this approach, dry etching is performed to In system compound semiconductor using compound magnetic field mold ECR-RIBE (electron cyclotron resonance-reactivity ion beam etching) equipment. With compound magnetic field mold ECR-RIBE equipment, it has the coil of two functions, a main coil and a subcoil, and emission of the magnetic field near [to etch] a sample is suppressed. According to this approach, chlorine and nitrogen are used as etching gas. A perpendicular cross section and a smooth etching side are acquired [the flow rate of chlorine gas / nitrogen gas] for internal pressure to an etching mask on condition that 0.5mTorr(s) or less to one.

[0003] According to the above-mentioned official report, in chlorine gas / nitrogen gas, when supplying gas at one or less rate, generating of a chlorine radical is controlled and etching by the chlorine ion serves as dominance from a chlorine radical. For this reason, even if it uses the ion which has about teneV low energy, the balance of evaporation of the chloride of In and the chloride of P can be maintained. Consequently, etching from which a perpendicular cross section and a smooth etching side are acquired to an etching mask is realizable.

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EFFECT OF THE INVENTION

[Effect of the Invention] According to this invention, the following effectiveness is acquired.

[0118] Dry etching of the III-V group who has a smooth etching side, and an II-VI group compound semiconductor can be performed by holding about 1 or 1 or more, and internal pressure for a chlorine flow rate / nitrogen flow rate to about 1 mTorr or 1 or more mTorr.

[0119] Moreover, dry etching of the III-V group who has a smooth etching side, and an II-VI group compound semiconductor can be performed by controlling independently the amount of a chlorine ion consistency, a chlorine radical consistency, and nitrogen ion density, and performing dry etching using the dry etching system equipped with the source of a radical, and the source of an ion beam.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] Conventionally, in the dry etching of a compound semiconductor, problems, such as difficulty, had the dry area of the etching side resulting from the difference of the vapor pressure of the reactant of an III group element and etching gas and vapor pressure with the reactant of V group element and etching gas being large, and control of a cross-section configuration.

[0005] The dry etching technique indicated by above-mentioned JP,7-66175,A is also for solving this problem. With this technique, by addition of nitrogen gas, chlorine gas decomposes and the amount of generation of a chlorine radical is controlled by about 1/3 among the chlorine ion generated and the chlorine radical. The above-mentioned problem is solved by this. Moreover, with the above-mentioned technique, in order to make the amount of generation of a chlorine radical into min, the pressure in a reaction chamber is set to 0.5 or less mTorr. Consequently, the desorption rate of the chloride of In and the chloride of P is balanced. The description of the above-mentioned technique is etching on the conditions from which chlorine radical concentration's becomes min. The above-mentioned official report does not show the quantitative data about the amount of generation and etching property of a chlorine ion.

[0006] Moreover, when aluminum is contained in the sample to etch, there is a problem to which it is no longer etched into or an etching rate falls greatly by aluminum $2O_3$ being formed of the residual moisture in a reaction chamber.

[0007] The place which this invention is made in view of the above-mentioned situation, and is made into the purpose As opposed to an III-V group and an II-VI group compound semiconductor, and the group III-V semiconductor that contains aluminum further Without reducing the amount of chlorine gas radical formation using the chlorine gas which added nitrogen gas It is in offering the semiconductor laser component which offered the dry etching approach by which a perpendicular cross section and a smooth etching side are acquired, and was produced using this dry etching approach, and its manufacture approach.

[Translation done.]

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MEANS

[Means for Solving the Problem] The etching approach by this invention with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies It is the etching approach which carries out dry etching of a group III-V semiconductor or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen. It is (the flow rate of the gas containing a halogen) / (flow rate of nitrogen gas) about ≥ 1 , and the pressure under etching reaction is about 1 mTorr or 1 or more mTorrs, and the above-mentioned purpose is attained by that.

[0009] With a certain operation gestalt, the 1st etching process which performs the above-mentioned dry etching, and the 2nd etching process which performs wet etching are included.

[0010] With a certain operation gestalt, the ion generated in said source of the plasma is accelerated, and it etches with the kinetic energy of this accelerated ion, heating a sample front face.

[0011] With a certain operation gestalt, the ion generated in said source of the plasma is accelerated, with the kinetic energy of this accelerated ion, it heats only near the front face of the sample containing an II-VI group compound, and the susceptor of this sample is cooled.

[0012] It etches with a certain operation gestalt, heating sample susceptor.

[0013] the 1st dry etching process which accelerates with the 1st acceleration voltage and etches the ion generated in said source of the plasma with a certain operation gestalt -- this -- it carries out after the 1st dry etching process, and the ion generated in this source of the plasma is accelerated with the 2nd acceleration voltage, the 2nd dry etching process to etch is included further, and this 1st acceleration voltage is larger than this 2nd acceleration voltage.

[0014] With a certain operation gestalt, said dry etching system is equipped with the source of a radical beam, and the source of an ion beam, and it performs dry etching, controlling independently the consistency of the radical generated by this source of a radical beam, and the consistency of the ion generated by this source of an ion beam, respectively.

[0015] With a certain operation gestalt, said compound semiconductor is formed of $\text{Al}_x\text{Ga}_{1-x}\text{In}_y\text{P}$ ($0 < x \leq 1$, $0 \leq y \leq 1$).

[0016] With a certain operation gestalt, said compound semiconductor is formed on the off substrate.

[0017] Other etching approaches by this invention with the dry etching system equipped with the source of the plasma which generates the plasma of three or more [about 1010cm -] consistencies It is the etching approach which carries out dry etching of a group III-V semiconductor or the II-VI group compound semiconductor using the mixed gas of the gas and the nitrogen gas containing a halogen. The 1st dry etching process which makes halogen ion density larger than a halogen radical consistency, and etches it, Halogen ion density is made smaller than a halogen radical consistency, the 2nd dry etching process to etch is included and the above-mentioned purpose is attained by that.

[0018] The etching system by this invention is equipped with the reaction chamber linked to the source of a radical beam, the source of an ion beam, and this source of a radical beam and this source of an ion beam, the sample susceptor prepared in this reaction chamber, and a load lock chamber, and the above-mentioned purpose is attained by that.

[0019] The manufacture approach of the semiconductor laser component by this invention The process which grows at least one compound semiconductor layer epitaxially on a semi-conductor substrate, The process which forms the mask by which patterning was carried out on one compound semiconductor layer even if there is none of these **, The process which etches to one compound semiconductor layer using the etching approach according to claim 1 to 10 even if this ** cannot be found, and forms a ridge stripe using this mask, The process which embeds this ridge stripe with a compound semiconductor is included, and the above-mentioned purpose is attained by that.

[0020] With a certain operation gestalt, said substrate is an inclination substrate, said at least one compound semiconductor layer contains the barrier layer, and the n mold AlGaInP cladding layer and p mold AlGaInP cladding layer which sandwich this barrier layer, and said ridge stripe contains this p mold AlGaInP layer.

[0021] With a certain operation gestalt, said p mold AlGaInP cladding layer has the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP, and the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.

[0022] With a certain operation gestalt, the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.

[0023] The semiconductor laser component by this invention is prepared on the substrate and this substrate. A barrier layer, It is the semiconductor laser component equipped with the ridge stripe containing n mold cladding layer which sandwiches this barrier layer, and p mold cladding layer. This ridge stripe It has the laser section which carries out laser oscillation, and a point, the base of this ridge stripe, the side face of this ridge stripe, and the include angle to make are about 60 degrees or more 90 degrees or less, and the above-mentioned purpose is attained by that.

[0024] With a certain operation gestalt, said point has the width of face which becomes thin in the shape of a taper from the width of face of said laser section, and this width of face is about 1 micrometer or less.

[0025] With a certain operation gestalt, said point has the width of face which becomes larger to the shape of a taper than the width of face of said laser section.

[0026] Other semiconductor laser components by this invention are semiconductor laser components equipped with the inclination substrate, and the n mold AlGaInP cladding layer formed on this substrate, a barrier layer and a p mold AlGaInP cladding layer, this p mold AlGaInP cladding layer has ridge structure with an almost symmetrical configuration, the current block layer is formed in the both sides of this ridge structure, and the above-mentioned purpose is attained by that.

[0027] With a certain operation gestalt, said p mold AlGaInP cladding layer has the 1st cladding layer of p mold AlGaInP, and the 2nd cladding layer of p mold AlGaInP, and the etching stopper layer is formed between this 1st cladding layer and this 2nd cladding layer.

[0028] With a certain operation gestalt, the layer for carrying out the monitor of the amount into which this 2nd cladding layer was etched is formed in said 2nd cladding layer of p mold AlGaInP.

[0029]

[Embodiment of the Invention] Below, the operation gestalt of this invention is explained at a detail.

[0030] (1st operation gestalt) As 1st operation gestalt of the dry etching approach by this invention, the dry etching approach for a group III-V semiconductor is explained. InP is used as a sample to etch. Chlorine gas and nitrogen gas are used as etching gas. Drawing 1 shows the configuration of the ECR-RIBE equipment (it is called ECR-RIBE equipment for short electron cyclotron resonance-reactivity ion beam etching and the following) used with this operation gestalt in ** type. In this equipment, the location of the sample to etch is located on the outside of the coil which generates a magnetic field.

[0031] As shown in drawing 1, ECR-RIBE equipment is connected with ECR source 101 and the ECR source, and is mainly equipped with the reaction chamber 102 and exhaust air pump system (not shown) for installing a sample. Ion and a radical are generated in ECR source 101. From a gas inlet 108, the chlorine gas and the nitrogen gas by which the flow rate was controlled are introduced into ECR source 101. Furthermore, 2.45GHz microwave will face the quartz aperture 107, and will be introduced into ECR source 101, and chlorine gas and nitrogen gas will be from a waveguide 106 in an excitation state. An electron sympathizes with the 875 gauss magnetic field generated with the coil 103, and it repeats gas and a collision, carrying out the circular motion. In this way, it is accelerated by the grid 104 and the chlorine ion and nitrogen ion which were generated in ECR source 101 are irradiated by the sample 105.

[0032] Although it is accelerated and a chlorine ion and nitrogen ion are irradiated by the sample 105, since it is not ionized, the chlorine radical and nitrogen radical which are generated in ECR source 101 are not accelerated. However, a chlorine radical and a nitrogen radical arrive at the front face of a sample 105 by diffusion, and contribute to etching. As for this ECR-RIBE equipment, unlike the compound magnetic field mold, the coil is not installed in the side face of a reaction chamber 102. For this reason, the magnetic field generated with a coil 103 is an emission magnetic field.

[0033] The ion and radical which were produced as mentioned above arrive at sample 105 front face, react with InP which is a sample, and In chloride and P chloride generate them. The boiling point of PCl_3 has the boiling point of 76 degrees C and PCl_5 as low as 162 degrees C, and evaporates P chloride easily.

[0034] On the other hand, the boiling point of 560 degrees C and InCl_3 has the boiling point of 608 degrees C and InCl_2 as high as 600 degrees C, and the boiling point of InCl cannot evaporate In chloride easily. For this reason, the layer of In chloride is formed in the front face of a sample 105. Since evaporation of In chloride is promoted, the acceleration voltage of ion serves as an important element, because the chlorine ion and nitrogen ion which were accelerated collide with the front face of a sample 105 from ECR source 101. Less than [acceleration voltage 300V], evaporation does not take place and In chloride is not etched.

[0035] Table 1 shows the conditions of etching of being used with this operation gestalt.

[0036]

[Table 1]

塩素	窒素	マイクロ波パワー	加速電圧	内圧	試料温度
3~20 SCCM	3.5~35 SCCM	200W(固定)	300~900 V	0.5~2.5 mTorr	室温 -300℃

[0037] In the conditions shown in Table 1, acceleration voltage is about 300v or more, and etching is the optimal. In addition, SiO₂ is used as a mask for etching.

[0038] The main results of having performed dry etching to below using the conditions shown in Table 1 are explained.

[0039] In the experiment, the chlorine flow rate was set as about 10 SCCM(s), about 2.5 mTorr(s) and sample temperature were set [acceleration voltage] as about 200 degrees C for the internal pressure under about 650V and reaction, the nitrogen flow rate was changed, and dry etching was performed. Evaporation of an III group compound can be promoted by heating sample susceptor and maintaining sample temperature at about 200 degrees C.

[0040] As a nitrogen flow rate, drawing 2 shows each cross-section photograph of InP to which about 35 SCCM(s) and drawing 3 performed about 7 SCCM(s) on condition that about 3.5 SCCM(s), and drawing 4 performed dry etching in a mimetic diagram.

[0041] Drawing 2 (a) shows the cross section etched using SiO₂ mask to an InP substrate. Although InP is etched as shown in this drawing, the base (etching side) is very ruined. Drawing 2 (b) is the perspective view of drawing 2 (a). Drawing 2 (b) also shows well that the base is ruined. In the case of drawing 3, etching is possible in the almost perpendicular direction to SiO₂ mask, and most base dry areas are lost. In the case of drawing 4, there is no base dry area and the etching side is smooth. However, side etching into which the mask bottom is also etched takes place, and perpendicular etching has not been performed to the mask.

[0042] The above-mentioned result shows that there is a boundary where the etching side of nitrogen flow rate [a chlorine flow rate /] is ruined between about 0.29 and 1.43. According to the experiment, it turned out that the ratios of the chlorine flow rate / nitrogen flow rate of the boundary are the about 1.0 neighborhoods. Moreover, it turns out that the smooth nature of an etching side has [the about 2.85 neighborhoods] the best ratio of a chlorine flow rate / nitrogen flow rate.

[0043] However, if the cross-section configuration of drawing 4 is seen, it is not perpendicular and side etching is considerably contained. In order to obtain a perpendicular cross section, it is necessary to stop the chemical reaction component in dry etching. Then, it etched by lowering sample temperature to about 100 degrees C. The result is shown in drawing 5 (conditions other than temperature are the same as the case of drawing 4).

[0044] By lowering sample temperature to 100 degrees C, a spatter component will become strong from chemical reactivity, and SiO₂ mask will retreat by being etched (it moves to a substrate side). For this reason, over etching happens and it becomes a trapezoid cross-section configuration. However, since the etching side is very smooth, it is satisfactory practically also in a trapezoid cross section.

[0045] As shown in drawing 4 and 5, when the chemical reaction component in etching is more superior than a spatter component, side etch happens, when a spatter component is more superior than chemical reactivity, a mask retreats and over-etching happens.

[0046] Next, examination of the etching conditions for obtaining a perpendicular cross section is explained.

[0047] In order to make chemical reactivity increase, sample temperature was made into about 150 degrees C, in order to raise an etching rate, the amount of supply of chlorine was increased up to about 11.5 SCCM(s) (a nitrogen flow rate is 3.5SCCM(s) as well as the case of drawing 4), and it etched. The result is shown in drawing 6 . A spatter component and a chemical reaction component can be balanced and a perpendicular etching cross section is realized so that drawing 6 may show. In this case, acceleration voltage is about 650V and internal pressure is still about 2.5 mTorr(s).

[0048] Each etching condition in drawing 2 -6 is collectively shown in Table 2.

[0049]

[Table 2]

	塩素 (SCCM)	窒素 (SCCM)	塩素／窒素 流量比	加速電圧 (V)	内圧 (mTorr)	試料温度 (℃)
図2	10	35	0.29	650	2.5	200
図3	10	7	1.43	650	2.5	200
図4	10	3.5	2.8	650	2.5	200
図5	10	3.5	2.8	650	2.5	100
図6	11.5	3.5	3.29	650	2.5	150

[0050] It will not be ruined if the ratio of a chlorine flow rate / nitrogen flow rate is about 1.0 or more. However, if this flow rate is made large to 6.4 or more, it will begin to be ruined for a while again. In consideration of the dry area of an etching side, the range of the optimum value of the flow rate of a chlorine flow rate / nitrogen flow rate is about 1.0 to 6.4.

[0051] drawing 16 -- the spectrum of plasma luminescence -- a result is shown. An optical result expresses a change of the nitrogen ion and chlorine ion to nitrogen concentration, and a chlorine radical on the strength at this rate. Each luminescence reinforcement shown in drawing 16 is standardized by the plasma luminescence reinforcement of only chlorine gas. As for nitrogen ion, 652.9nm was observed, and, as for the chlorine ion, luminescence by 727.9nm was observed, as for 450.8nm and a chlorine radical. Luminescence by 652.9nm only in the case of chlorine gas is a noise, and is not luminescence by nitrogen ion.

[0052] The luminescence reinforcement of nitrogen ion increases simply in proportion to the addition of nitrogen. Although the luminescence reinforcement by the chlorine ion increases by addition of nitrogen, the addition concentration of nitrogen shows maximum at about 23%. This maximum is about 1.4 times in nitrogen additive-free. Then, according to the increment in nitrogen addition concentration, slight luminescence reinforcement by the chlorine ion decreases, and is saturated with one about 1.3 times [in nitrogen additive-free] the value of this. although it increases about 10% by addition of nitrogen, it comes out to this extent and the luminescence reinforcement by the chlorine radical is saturated, and even if it adds nitrogen further, it does not increase.

[0053] Below, change of the above-mentioned luminescence reinforcement is explained as compared with an etching property.

[0054] When a chlorine flow rate / nitrogen flow rate is less than one, the nitrogen concentration in drawing 16 is a field (field **) exceeding 50%. In field **, although chlorine ion reinforcement is about 1.3 or more times to the case of pure chlorine (nitrogen additive-free), nitrogen ionic strength has increased about 3 times. That is, it is thought with superfluous nitrogen ion by carrying out the spatter of the P chloride with vapor pressure high among In chloride and P chloride alternatively that it is ruined.

[0055] When a chlorine flow rate / nitrogen flow rate is 6.4 or less [about 1 or more], the nitrogen concentration of drawing 16 is equivalent to about 50% or less of field (field **) about 13% or more. In this field, the reinforcement of nitrogen ion does not increase so much, but balance of the desorption from the front face of In chloride and P chloride can be taken, and the smooth etching side is realized.

[0056] When a chlorine flow rate / nitrogen flow rate exceeds 6.4, the nitrogen concentration of drawing 16 is equivalent to about 13% or less of field (field **). In field **, it is ruined again. Since the desorption of In chloride which this generated, and P chloride mainly happens with heat energy from the spatter effectiveness, it is thought that it is because the alternative desorption of P chloride happens.

[0057] As stated above, the effectiveness which adds nitrogen gas not only promotes generation of a chlorine ion, but in this invention, the big description has it in the place which promotes the desorption of the chloride of an III group or V group according to the spatter effectiveness by the nitrogen ion itself. This is also the same as when this invention is applied to an II-VI group compound semiconductor.

[0058] In the above explanation, as an ingredient to etch, although a group's III-V semiconductor InP was used, the ingredient of an AlGaInP system, an AlGaInN system, and the ZnMgSSe system of an II-VI group compound semiconductor may be used instead of InP so that it may explain later. Moreover, although an etching rate falls, etching is possible even if it holds substrate temperature to a room temperature.

[0059] (2nd operation gestalt) Below, the dry etching approach for a group III-V semiconductor is explained as 2nd operation gestalt of the dry etching approach by this invention. More specifically, the dry etching approach to etch is explained with the kinetic energy of the accelerated ion, heating only a sample front face, without raising the temperature of the whole sample.

[0060] InP is used as an etching sample and SiO₂ is used as an etching mask. In addition, the approach of this operation gestalt is applicable to etching of an II-VI group compound semiconductor.

[0061] As the operation gestalt of the above 1st described, when raising sample temperature, the chemical reaction component in dry etching becomes dominance from a spatter component, and side etching into which the mask bottom is also etched takes place. However, if sample temperature is lowered, since a spatter component will become strong, over-etching to which a mask retreats is caused, or an etching base is ruined.

[0062] So, with this operation gestalt, it is made to stick to the sample maintenance fixture which produced the sample with aluminum, and it etches, cooling this maintenance fixture.

[0063] By the grid, it is accelerated by hundreds V and the ion generated in an ECR source is irradiated by the sample with kinetic energy. The radical generated in an ECR source is not accelerated. Since the energy per radical has many radicals generated with 20-30eV although it is small, the total energy received from a radical has a quite large sample front face. Thus, in order that a sample front face may obtain many ion and the energy of a radical, even if it does not go up the temperature of a sample substrate, the same effectiveness as the case where the sample itself is raised to hundreds of degrees C is acquired. That is, by heating the front face of a sample in this way, evaporation of the chloride of an III group or II group is promoted, and an etching rate is improved.

[0064] ECR-RIBE equipment is used, about 200W and internal pressure are set to about 2.5 mTorr(s), it sets [a chlorine flow rate / about 11.5 SCCM(s) and a nitrogen flow rate] acceleration voltage to about 650 V for about 3.5 SCCM(s) and microwave power, and drawing 8 shows the cross section of InP at the time of performing dry etching to InP.

[0065] In this case, it is not heating to the whole sample. The sample maintenance fixture produced with aluminum is equipped with the sample. A sample maintenance fixture is put on the sample susceptor by which water cooling was carried out. Only the part near the front face of a sample is heated by this, and the temperature of the part except this part does not rise by it. A sample is protected from a thermal damage. Especially the thing done like this is effective in etching the sample containing an II-VI group compound. Because, since the crystal growth temperature (about 260 degrees C) of an II-VI group compound semiconductor is low, in order to prevent crystalline degradation, it is necessary to make etching temperature lower (about 250 degrees C or less) than crystal growth temperature.

[0066] As the operation gestalt of the above 1st described, the configuration of an etching cross section reflects the balance of the spatter component to etch and a chemical reaction component. That is, when a spatter component is dominance, over-etching of the cross section is carried out, and when a chemical reaction component is dominance, side etching takes place.

[0067] Although the temperature of the whole sample is near a room temperature according to this operation gestalt as drawing 8 shows, the cross section is almost perpendicular and has balanced the chemical reaction component and the spatter component. The cross section of drawing 8 shows the same cross-section configuration as the case of drawing 6, when it etches by setting sample temperature as 150 degrees C. That is, the result shown in drawing 8 which etched without heating is the same as the result shown in drawing 6 which etched by setting sample temperature as 150 degrees C about the cross-section configuration. However, the etching rate in the case of drawing 8 is lower than it in the case of drawing 6 25%.

[0068] In addition, with this operation gestalt, although sample temperature is set up near the room temperature, it can also make the difference [chloride / of an III group] of sublimation small by cooling sample susceptor at 0 degree C or less, and controlling sublimation of V group's chloride. This can perform dry etching from which a perpendicular cross section and a smooth etching side are acquired.

[0069] (3rd operation gestalt) As 3rd operation gestalt of the dry etching approach by this invention, the dry etching approach for a group III-V semiconductor is explained. The dry etching approach of more specifically performing two steps of etching of different conditions is explained. As a sample, SiO₂ is used as InP and an etching mask, and chlorine and nitrogen are used as etching gas.

[0070] The 1st dry etching is first performed using ECR-RIBE equipment. In this 1st dry etching, by setting internal pressure to about 1 or less mTorr, and setting acceleration voltage to about 300v or more, the collision between gas molecules is suppressed and ion density is made larger than a radical consistency. About 1 or more and sample temperature are set as about 100 degrees C for a chlorine flow rate / nitrogen flow rate. In this case, etching by the spatter component becomes dominance from a chemical reaction component, the high-speed dry etching in a perpendicular direction progresses to a sample front face, and the configuration near a desired configuration is formed.

[0071] The 1st dry etching of the above has the above and a comparatively high etching rate by about 1000A/. When etching at high speed, in the etched side face or etching side, the damage by which induction is carried out to processing arises, or it is ruined. This is because a crystal defect arises in a sample, when it is accelerated on the high electrical potential difference beyond 300V and the halogen ion generated in an ECR source is irradiated by the sample. Moreover,

since the boiling points of a halogenide differ to an III group (or II group) and V groups (or VI group), when the stoichiometry in an etching side shifts, it is because the III group (or II group) elements in an etching side increase in number more than V group (or VI group) element in an excess.

[0072] Next, it continues at the 1st dry etching and the 2nd dry etching is performed. It is removing the layer which has the processing induction damage produced by the 1st dry etching as a purpose which performs this 2nd dry etching. Moreover, it is removing the devastated field and making it smooth by the 1st dry etching, when a dry area's arises in an etching side. In order to attain the above-mentioned purpose, about 3 or more and internal pressure are set as about 2 or more mTorr, it sets about 300v or less and sample temperature as about 200 degrees C for acceleration voltage, and the 2nd dry etching performs a chlorine flow rate / nitrogen flow rate. In this case, the collision between gas molecules increases and the radical consistency becomes large from ion density. Furthermore, since a mean free path becomes small, the chemical reaction component acts strongly from a spatter component.

[0073] Since the processing induction damage done to a crystal is small, etching under the strong conditions of the above chemical reactivity can remove a layer including many processing induction damages produced in the 1st dry etching. When ruined in the 1st dry etching, the devastated field can be made smoother by the 2nd dry etching of the above.

[0074] The 1st dry etching is a chlorine flow rate. Although it can carry out on condition that /nitrogen flow rate abbreviation ≥ 1 , internal pressure abbreviation ≤ 1 mTorr, and acceleration voltage abbreviation ≥ 300 V, a chlorine flow rate / nitrogen flow rate abbreviation ≥ 3 , internal pressure abbreviation ≤ 0.5 mTorr, and acceleration voltage abbreviation ≥ 600 V are more more desirable as optimum conditions.

[0075] Although the 2nd dry etching can be performed on condition that a chlorine flow rate / nitrogen flow rate abbreviation ≥ 3 , internal pressure abbreviation ≥ 2 mTorr, and acceleration voltage abbreviation ≤ 300 V, a chlorine flow rate / nitrogen flow rate abbreviation ≥ 10 , internal pressure abbreviation ≥ 3 mTorr, and acceleration voltage abbreviation ≤ 100 V are more more desirable as optimum conditions.

[0076] Drawing 12 is the sectional view showing the process of the dry etching by this operation gestalt. First, as shown in drawing 12 (a), SiO₂ mask 1202 by which patterning was carried out is formed on the InP substrate 1201. Then, as shown in drawing 12 (b), the 1st dry etching is performed. According to this process, the damage layer 1203 by which induction is carried out to processing arises on an etching front face. Next, as shown in drawing 12 (c), the 2nd dry etching is performed. In the 2nd dry etching, a chlorine ion consistency is small and a chlorine radical consistency is larger than the case of the 1st dry etching. By performing the 2nd dry etching, the damage layer 1203 by which induction is carried out to processing is removed, and a perpendicular side face and a smooth etching side can be formed to a mask 1202.

[0077] In addition, in the above explanation, the size relation of the chlorine ion consistency and chlorine radical consistency in the 1st and 2nd dry etching was changed by changing internal pressure, flow rate, and acceleration voltage. Instead, the 1st and the 2nd dry etching may be performed by changing only acceleration voltage. That is, the 1st and 2nd dry etching is a chlorine flow rate. Using conditions with /nitrogen flow rate abbreviation ≥ 3 , an internal pressure abbreviation ≥ 2 mTorr, and a sample temperature of about 200 degrees C, in the 1st dry etching, acceleration voltage is set as about 900V, and acceleration voltage is set as about 100 V by the 2nd dry etching. On such conditions, even if it performs dry etching, etching without a dry area is realizable.

[0078] (4th operation gestalt) Below, the etching approach for a group III-V semiconductor is explained as 4th operation gestalt of the etching approach by this invention. More specifically, the etching approach of performing two steps of etching, dry etching and wet etching, is explained. As a sample, SiO₂ is used as InP and an etching mask, and chlorine and nitrogen are used as etching gas. As an etching solution of wet etching, a hydrochloric acid, an acetic acid, and hydrogen peroxide solution are used.

[0079] First, 1st etching (dry etching) is performed using ECR-RIBE equipment. In this 1st etching, abbreviation ≥ 1 and internal pressure are made to about 2 or more mTorr, and about 300v or more and sample temperature are made [a chlorine flow rate / nitrogen flow rate] into about 100 degrees C or more for acceleration voltage. Although the 1st etching is possible on the above-mentioned conditions, for about 3.5 SCCM(s) and sample temperature, about 150 degrees C and acceleration voltage are [a chlorine flow rate / about 11.5 SCCM(s) and a nitrogen flow rate / about 650V and internal pressure of optimum conditions] about 2.5 mTorr(s). On such conditions, a sample is processible into a predetermined configuration. A layer including the processing induction damage generated by the 1st etching is removed by the 2nd etching explained below.

[0080] Drawing 7 shows typically the configuration of the spin etching system used for the 2nd etching. 2nd etching, i.e., wet etching, is performed in a reaction chamber 705. The sample 701 by which dry etching was carried out [above-mentioned] is installed on the sample maintenance base 702. The sample maintenance base 702 holds a sample 701 by the vacuum chuck, and rotates with a predetermined rotational speed. The mixed liquor of the hydrochloric acid which is

maintained by the etchant tank 704 and saved to predetermined temperature at it, an acetic acid, and hydrogen peroxide solution comes out of a nozzle 703, and flows and falls on a sample 701. The core of a nozzle 703 and the sample maintenance base 702 is in agreement, and a nozzle 703 reciprocates the between to a predetermined distance to radial [of the core of the sample maintenance base 702 to a sample maintenance base]. While a nozzle 703 fails to flow liquid in the sample 701 to rotate, very uniform wet etching is performed by reciprocating radial. In this way, the damage layer by which induction is carried out to processing produced by the 1st etching is removed. The temperature of 3:36:1 and mixed liquor of the mixing ratio of a hydrochloric acid, an acetic acid, and hydrogen peroxide solution should just be 20 degrees C.

[0081] Since wet etching does not contain a spatter component, some damages which are given by using dry etching can also be prevented by using wet etching. For this reason, the smooth nature of an etching side can be improved further.

[0082] In this operation gestalt, as a solution used for the 2nd etching, although a hydrochloric acid, an acetic acid, and hydrogen peroxide solution were used, it may replace with this and the mixed liquor of the mixed liquor of the mixed liquor of a sulfuric acid, hydrogen peroxide solution, and water, a hydrochloric acid, and a phosphoric acid or saturation bromine water, and a methanol may be used. What is necessary is just the solution from which induction is carried out to processing produced by the 1st etching in short, and a damage layer can be removed.

[0083] (5th operation gestalt) The dry etching system which equipped below with the source of a radical beam and the source of an ion beam other than an ECR source, and the dry etching approach using it are explained.

[0084] Drawing 9 shows typically the configuration of the dry etching system of this operation gestalt. This equipment is equipped with the source 902 of a radical beam and the source 903 of an ion beam other than ECR source 904 and a reaction chamber 901. The source 902 of a radical beam and the source 903 of an ion beam are connected to the reaction chamber 901.

[0085] All over the reaction chamber 901, it has the sample maintenance base 905 holding a sample 906. The chlorine ion generated by the chlorine radical generated in the source 902 of a radical beam, the chlorine ion generated in the source 903 of an ion beam, and ECR source 904, a chlorine radical, and nitrogen ion are irradiated by the sample 906. A sample 906 is sent to a reaction chamber 901 from the load lock chamber 900 for paying a sample 906 to a reaction chamber 901. A reaction chamber 901 is exhausted by about 10 to 6 or less Torrs by the exhaust air system (not shown).

[0086] In the source 902 of a radical beam, RF RF will be added and chlorine gas will be in the plasma state. A chlorine ion and a chlorine radical occur by this. Since a mean free path is several centimeters, it collides with other atoms or an electron and a chlorine ion disappears in the source 902 of a radical, or a reaction chamber 901 when not accelerated, it does not reach to a sample. The generated radical arrives even at a sample front face by diffusion, and contributes to a reaction.

[0087] On the other hand, also in the source 903 of an ion beam, RF RF will be added and chlorine gas will be in the plasma state. A chlorine ion and a chlorine radical occur by this. By changing the electrical potential difference applied to the drawer electrode 9031, by changing the rate of the chlorine ion pulled out from the source 903 of an ion beam, and a chlorine radical, many chlorine ions are pulled out and irradiated on a sample front face from a chlorine radical.

[0088] In ECR source 904, as the 1st operation gestalt described, gas is decomposed and ion and a radical are generated. Nitrogen gas is introduced into ECR source 904 in this operation gestalt.

[0089] The consistency of the radical which contributes to the smooth nature of the gas which contributes to a reaction, and the consistency of the ion contributed to an etching rate are independently controllable, respectively by having the ion source, a source of a radical, and an ECR source as mentioned above. For this reason, high-speed etching is possible, with the smooth nature of an etching side maintained. It becomes easy to control the smooth nature of an etching rate, a cross-section configuration, and an etching side. As the 1st operation gestalt described in the case of the dry etching of InP by the mixed gas of chlorine and nitrogen, using SiO₂ as a mask, P chloride is sublimated easily, and since it is hard to sublimate In chloride, the layer of In chloride will be formed in a sample front face. What is necessary is just to use the kinetic energy of the accelerated chlorine ion and nitrogen ion, in order to make the layer of this In chloride sublimate.

[0090] Then, what is necessary is to make [more] a chlorine ion flow rate than a chlorine radical flow rate, to accelerate by the high voltage of about 300v or more, and just to supply a chlorine ion and nitrogen ion. What is necessary is just to set sample temperature as about 150 degrees C or more, in order to make an etching rate high.

[0091] According to this operation gestalt, the dry etching of InP in which about 300v or more and the nitrogen ion from an ECR source are [about 10 or more SCCMs and acceleration voltage] about 3 or less SCCMs for the chlorine ion flow rate from about 1 or more SCCMs and the source of an ion beam, and the chlorine radical flow rate from the source of a radical beam has a smooth etching side is possible. Furthermore, dry etching in which a chlorine radical flow rate has the cross section about 1 SCCM and a chlorine ion flow rate has [the acceleration voltage of about 10 SCCM(s) and a chlorine ion / about 600v or more and the nitrogen flow rate of an ECR source] about 3 SCCM(s) and sample

temperature perpendicular in a cross section on the conditions which are about 150 degrees C, and a smooth etching side is realized.

[0092] (6th operation gestalt) Below, the manufacture approach of a semiconductor laser component is explained using the etching approach explained with the operation gestalt of the above 1-5ths. The diameter conversion laser of a spot is used as a semiconductor laser component. Drawing 10 (a) - (c) shows typically the cross section of the structure of the diameter conversion laser of a spot.

[0093] This diameter conversion laser of a spot has the laser section 1010 and the spot-size transducer (point) 1011, as shown in drawing 10 (a). The laser section 1010 has the stripe configuration which has fixed width of face and thickness. As for the spot-size transducer 1011, width of face is [width of face] small toward the outgoing radiation edge 1012 at the shape of a taper. A laser beam is changed into the path m of the outgoing radiation edge (tip of a point 1011) 1012 of the spot-size transducer 1011 from the diameter of a spot in the laser section 1010, while guiding the spot-size transducer 1011. Width of face m is [the include angle of about 1 micrometer or less (typically about 0.6 micrometers) and a cross section of the outgoing radiation edge 1012] about 90 degrees.

[0094] Drawing 10 (b) shows the cross section in alignment with line A-A' of drawing 10 (a). As shown in drawing 10 (b), epitaxial growth of the n-InP layer 1002, the n-InGaAsP cladding layer 1003, a barrier layer 1004, the p-InGaAsP cladding layer 1005, and the p-InP cap layer 1007 is carried out one by one on the n-InP substrate 1001. these layers -- the mesa stripe (ridge stripe) 1014 -- constituting -- the mesa stripe 1014 -- half-- it is embedded by insulating InP1006. The p lateral electrode 1009 is formed on the p-InP cap layer 1007, and the n lateral electrode 1008 is formed all over the rear face of a substrate 1001.

[0095] The electron hole poured in from the p lateral electrode 1009 is recombined by the electron and barrier layer 1004 which were poured in from the n lateral electrode 1008. Luminescence takes place under the p lateral electrode 1009, and carries out laser oscillation by being shut up in a resonator end face.

[0096] Drawing 10 (c) shows the cross section in alignment with line B-B' of drawing 10 (a). The laser section 1010 differs in the width of face of a barrier layer 1004 from the spot-size transducer 1011 so that drawing 10 (b) and drawing 10 (c) may be compared and understood. That is, the direction of the width of face of the barrier layer 1004 of the spot-size transducer 1011 is small.

[0097] Below, the manufacture approach of the diameter conversion laser of a spot is shown, referring to drawing 11 (a) - (g). Drawing 11 (a) - (g) is the mimetic diagram of the cross section of the laser section 1010. The width of face of a barrier layer etc. only differs, and the spot-size transducer 1011 is manufactured by the laser section 1010 and coincidence.

[0098] First, as shown in drawing 11 (a), sequential growth of the n-InP layer 1102, the n-InGaAsP cladding layer 1103, a barrier layer 1104, and the p-InGaAsP cladding layer 1105 is carried out on the n-InP substrate 1101 by metal-organic chemical vapor deposition (MOVPE law). Then, as shown in drawing 11 (b), SiO₂ mask 1106 which has a predetermined configuration is formed on the p-InGaAsP cladding layer 1105.

[0099] Next, as shown in drawing 11 (c), the mesa stripe (ridge stripe) 1109 is formed using ECR-RIBE equipment by the etching approach explained with the operation gestalt of the above 1-5ths. Chlorine flow rate / nitrogen flow rate abbreviation ≥ 1 , and microwave power about 200W, the internal pressure of about 2 or more mTorr, the sample temperature of about 150 degrees C or more, and the acceleration voltage of the conditions of etching are about 300v or more. The side face of a mesa stripe and the front face of a substrate 1101 which are formed on this condition, and the include angle theta to make are about 60 degrees or more 90 degrees or less, as shown in drawing 11 (c) and (g). next, it is shown in drawing 11 (d) -- as -- MOVPE -- law -- SiO₂ mask 1106 -- as the mask of selective growth -- using -- crystal growth -- carrying out -- the mesa stripe 1109 -- half-- it embeds by insulating InP1107. after removing SiO₂ mask 1106, it is shown in drawing 11 (e) -- as -- MOVPE -- the p-InGaAsP cap layer 1108 is grown up by law. Finally, as shown in drawing 11 (f), it heat-treats by vapor-depositing the p lateral electrode 1111 and the n lateral electrode 1110, and ohmic contact is formed.

[0100] As explained above, according to this invention, a cavity and waveguide with the front face of the substrate 1101 as shown in drawing 11 (g), the side attachment wall of the mesa stripe whose include angle theta to make is about 60 degrees - 90 degrees, and outgoing radiation opening of 1 micrometer or less of **** can be formed by etching with ECR-RIBE equipment using chlorine gas and nitrogen gas. According to the approach of this invention, it is avoidable that the reverse mesa (the above-mentioned include angle theta is 90 degrees or more) to which the dependability of a component is fallen is formed.

[0101] In addition, in the above-mentioned explanation, although the width of face of a point 1011 is narrower to the shape of a taper than the width of face of the laser section 1010, it may become larger to the shape of a taper than the width of face of the laser section 1010.

[0102] In the above operation gestalt, although ECR-RIBE equipment was used, it may replace with this and the dry etching system equipped with the source of the inductive-coupling mold plasma, the dry etching system equipped with the source of the Helicon mold plasma, or the dry etching system equipped with the source of the NLD mold plasma may be used.

[0103] Moreover, although the above operation gestalt explained using InP as a compound semiconductor, other III-V groups or II-VI group compound semiconductors may be used. In addition, in the above explanation, although chlorine gas was used, the gas containing chlorine, a bromine, or iodine may be used.

[0104] (7th operation gestalt) Below, the manufacture approach of other semiconductor laser components is explained using the etching approach explained with the operation gestalt of the above 1-5ths, referring to drawing 13 (a) - (d). In this operation gestalt, the compound semiconductor etched contains aluminum (aluminum).

[0105] first, it is shown in drawing 13 (a) -- as -- MOVPE -- on the n mold GaAs substrate 1301 by law A n mold GaAs buffer layer (un-illustrating), n mold $\text{Al}_x\text{Ga}_{1-x}\text{In}_1\text{-x-yP}$ ($0 < x \leq 1$, $0 \leq y \leq 1$, and the following) AlGaInP The cladding layer 1302 called for short, the multiplex quantum well barrier layer 1303 constituted by an AlGaInP barrier layer and the GaInP well layer, the 1st cladding layer 1304 of p mold AlGaInP, the GaInP etching stopper layer 1305 (thickness: about 5nm), Epitaxial growth of the 2nd cladding layer 1306 of p mold AlGaInP is carried out. The GaAs substrate 1301 is an off substrate which inclines in the [110] directions about 10 degrees from the field (100).

[0106] Next, in order to form a ridge, 4 micrometers of **** and SiO₂ mask 1307 with a thickness of about 0.5 micrometers by which patterning was carried out are formed on the p mold AlGaInP layer 1306.

[0107] Next, as shown in drawing 13 (b), a ridge 1313 is formed by using SiO₂ mask 1307 as an etching mask using the dry etching approach explained by the above 1-5ths. As conditions for etching, a chlorine flow rate / nitrogen flow rate is set as about 3.1 by setting a chlorine flow rate to about 11 SCCM(s), and setting nitrogen to about 3.5 SCCM(s). In addition, acceleration voltage is [about 2.5 mTorr(s) and the sample temperature of about 650V and internal pressure] about 100 degrees C. The ridge 1313 of symmetrical trapezoidal shape is obtained by performing dry etching on such conditions.

[0108] Usually, by etching using an inclination substrate, as shown in drawing 14 (b), a ridge does not become the configuration of bilateral symmetry. Since the substrate inclines from a field (100), in the wet etching using the etching reagent of a sulfuric-acid system, the inclination of the side face in the pars basilaris ossis occipitalis of a ridge becomes loose, and a ridge serves as an unsymmetrical configuration. Consequently, impregnation of the carrier to a barrier layer and light close, eye ** becomes an ununiformity, and the transverse mode becomes unstable. This becomes remarkable when operating laser at an elevated temperature especially.

[0109] Moreover, in the semiconductor laser of an AlGaInP system, in order to short-wavelength-ize wavelength of a laser beam, whenever [tilt-angle] is enlarged increasingly. The asymmetry of a ridge becomes larger as whenever [tilt-angle] becomes large. As shown in drawing 14 (a), in spite of using an OFF substrate by performing dry etching on the above-mentioned conditions according to this operation gestalt, the ridge 1412 with a symmetrical configuration can be formed.

[0110] The dry etching for carrying out ridge formation is stopped in the etching stopper layer 1305, as shown in drawing 13 (b). The thickness of the 2nd cladding layer 1306 of p mold AlGaInP etched by dry etching is about 1.5 micrometers. As the 2nd operation gestalt explained such a thick layer, about 1.3 micrometers is first etched by the 1st dry etching with a strong spatter component, and the about 0.2-micrometer p molds AlGaInP remaining by the 2nd dry etching with a strong chemical reaction component are etched after that. If it carries out like this, the damage by etching will not be exerted on the layer below the etching stopper layer 1305.

[0111] Moreover, as the 3rd operation gestalt explained, the 2nd cladding layer 1306 with a thickness of about 1.3 micrometers may be etched by dry etching with a strong spatter component, and the 2nd about 0.2-micrometer remaining cladding layers 1306 may be etched by wet etching as the 2nd etching.

[0112] After forming a ridge 1313, as shown in drawing 13 (c), the n mold GaAs current block layer 1309 which is n mold embedding layer is grown up alternatively, using SiO₂ mask 1307 as it is.

[0113] Next, SiO₂ mask 1307 is removed, and as shown in drawing 13 (d), the p mold GaAs contact layer 1310 is grown up. Finally, the p lateral electrode 1312 is formed in the rear face of the n mold GaAs substrate 1301 on the n lateral electrode 1311 and the contact layer 1310, and laser structure is completed.

[0114] In the manufacture approach of the semiconductor laser component of this operation gestalt, by setting the flow rate of halogen gas and nitrogen gas as formation of a ridge 1313 in an abbreviation $1.4 \leq \text{chlorine flow rate} / \text{nitrogen flow rate} \leq \text{about } 4.0$ range Although the base of a ridge 1313, the side face of a ridge 1313, and the include angle theta to make use an OFF substrate while turning into about 60 - 90 degrees, they can manufacture a semiconductor laser component with a ridge configuration with sufficient symmetry. For this reason, the carrier to a barrier layer shuts up,

light closes, and eye ** does not become an ununiformity, but a semiconductor laser component with high dependability with the stable transverse mode is obtained. Furthermore, according to this operation gestalt, an etching rate does not fall in spite of etching of the compound semiconductor containing aluminum. In addition, in the above explanation, in the process which carries out dry etching of the 2nd cladding layer of p mold AlGaInP, conditions are changed in the phase which etched about 1.3 micrometers of AlGaInP cladding layers by the 1st dry etching, and the 2nd dry etching is performed. Here, in order to detect easily (monitor), as it is shown in the part of this thickness of an AlGaInP cladding layer at drawing 15 (a) that the AlGaInP cladding layer with a thickness of about 1.3 micrometers was etched, the GaInP layer 1500 (thickness: about 10nm) from which the 2nd cladding layer 1506 of AlGaInP and a presentation differ may be inserted beforehand.

[0115] Since the GaInP layer 1500 does not contain aluminum when the 2nd cladding layer of AlGaInP is etched and etching advances by the GaInP layer 1500, carrying out spectrographic analysis from the plasma by forming the GaInP layer 1500, the value of spectrographic analysis changes. It is correctly detectable that about 1.3 micrometers of the 2nd cladding layer were etched with this change. And what is necessary is to perform the 2nd dry etching and just to etch that of the 2nd cladding layer of the remaining about 0.2-micrometer thickness, as etching conditions are changed and it is shown in drawing 15 (b). By carrying out like this, further, there are few damages at the time of etching, and its controllability is good, and they can manufacture the semiconductor laser component which has a uniform property.

[0116] The desorption of aluminum $2O_3$ can be promoted by sputtering by increasing the amount of chlorine ion generation, without the amount of chlorine radical formation making it decrease, when aluminum is contained in the sample to etch according to this operation gestalt, even if aluminum $2O_3$ is formed of the residual moisture in a reaction chamber. Moreover, a chlorine radical and aluminum are made to react, and aluminum serves as an aluminum chloride and ****s. For this reason, the problem to which a sample is no longer etched into or an etching rate falls is avoidable.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The mimetic diagram of ECR-RIBE equipment

[Drawing 2] (a) It is a sectional view after the dry etching [in / it reaches and / in (b) / 1 operation gestalt of this invention] of InP.

[Drawing 3] The sectional view after the dry etching of InP in 1 operation gestalt of this invention

[Drawing 4] The sectional view after the dry etching of InP in 1 operation gestalt of this invention

[Drawing 5] The sectional view after the dry etching of InP in 1 operation gestalt of this invention

[Drawing 6] The sectional view after the dry etching of InP in 1 operation gestalt of this invention

[Drawing 7] The configuration sectional view of the spin etching system for carrying out wet etching to homogeneity, rotating a substrate

[Drawing 8] The sectional view after the dry etching of InP in 1 operation gestalt of this invention

[Drawing 9] The configuration sectional view of the dry etching system equipped with the source of a radical beam, the source of an ion beam, and the ECR source

[Drawing 10] (a) - (c) -- 1 operation gestalt of this invention -- the sectional view of the diameter conversion laser of a spot to kick

[Drawing 11] (a) - (g) is the production process sectional view of the diameter conversion laser of a spot of drawing 10.

[Drawing 12] (a) - (c) is the mimetic diagram of the two-step dry etching of different conditions in 1 operation gestalt of this invention.

[Drawing 13] (a) - (d) is the production process sectional view of the semiconductor laser in 1 operation gestalt of this invention.

[Drawing 14] (a) It is the configuration sectional view of semiconductor laser where it reaches and (b) compares the symmetric property of a ridge.

[Drawing 15] (a) It is the configuration sectional view of semiconductor laser where it reached and (b) was equipped with the monitor layer of the amount of etching into the cladding layer.

[Drawing 16] the spectrum of plasma luminescence -- drawing showing a result

[Description of Notations]

101 ECR Source

102 Reaction Chamber

103 Coil

104 Grid

105 Sample

702 Sample Maintenance Base

703 Nozzle

704 Etchant Tank

705 Reaction Chamber

902 Source of Radical Beam

903 Source of Ion Beam

904 ECR Source

9031 Drawer Electrode

1001 N-InP Substrate

1002 n-InP

1003 N-InGaAsP Cladding Layer

1004 'Barrier' Layer
1005 P-InGaAsP Cladding Layer
1006 Half--- Insulating InP
1007 P-InP Cap Layer
1008 N Lateral Electrode
1009 P Lateral Electrode
1010 Laser
1011 Spot-Size Transducer
1201 N-InP Substrate
1202 SiO₂ Mask
1203 Processing Induction Damage Layer

[Translation done.]

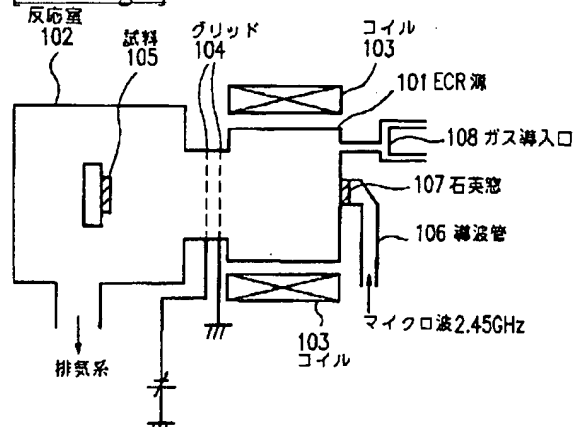
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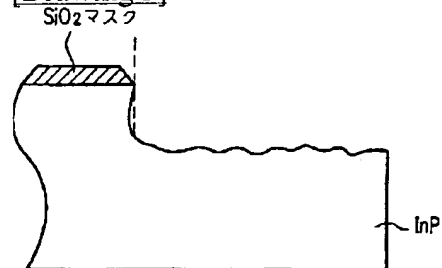
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DRAWINGS

[Drawing 1]

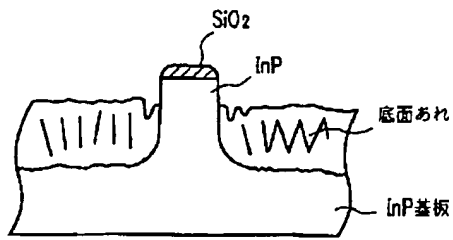


[Drawing 3]

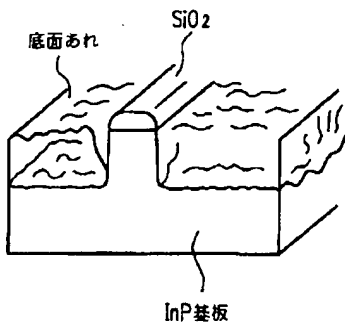


[Drawing 2]

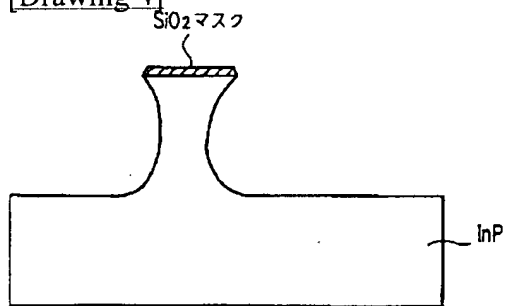
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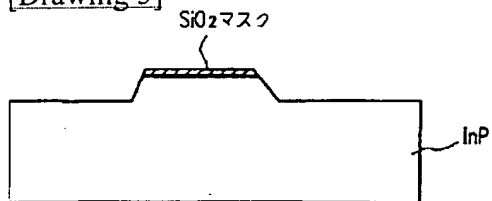
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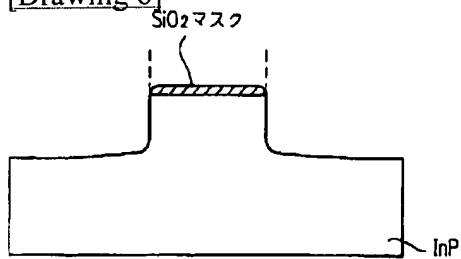
[Drawing 4]



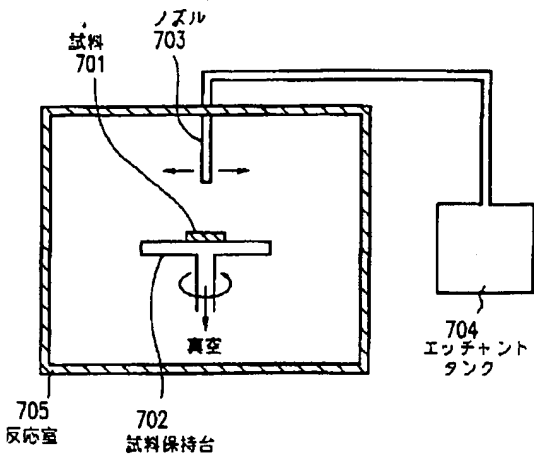
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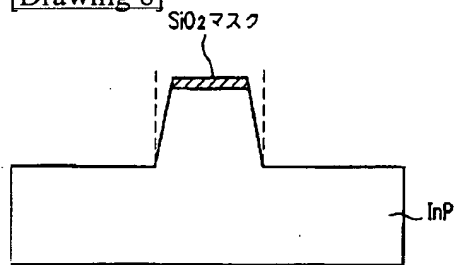
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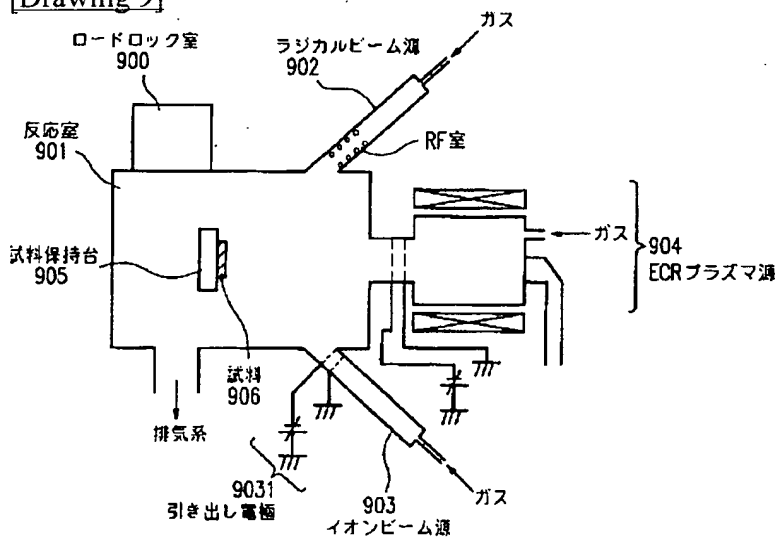
[Drawing 7]



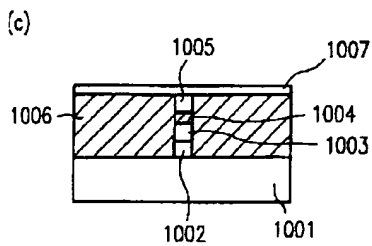
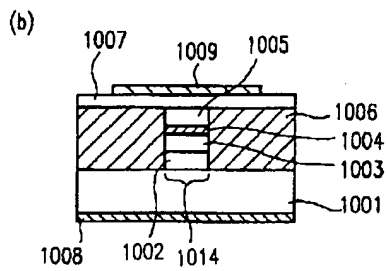
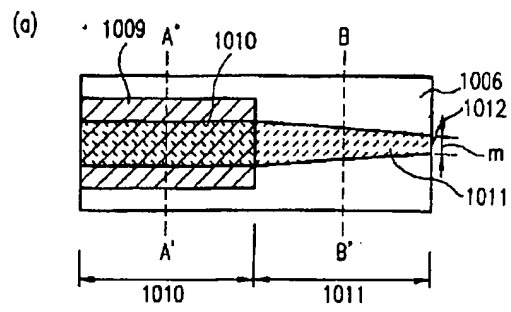
[Drawing 8]



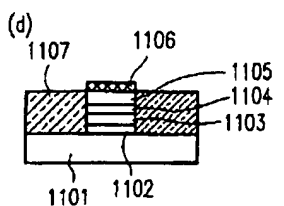
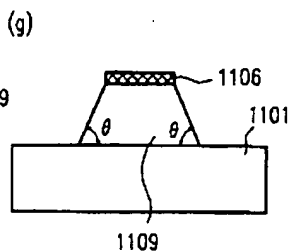
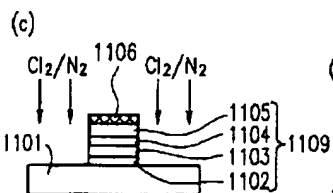
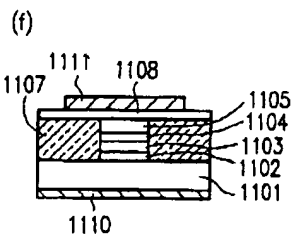
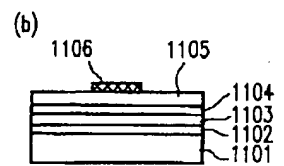
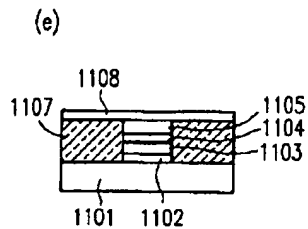
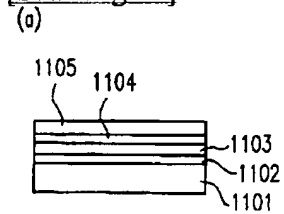
[Drawing 9]



[Drawing 10]

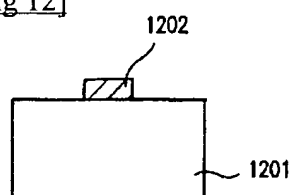


[Drawing 11]

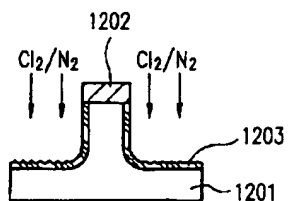


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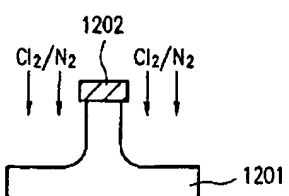
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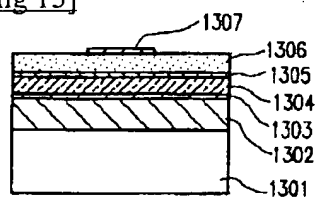


(c)

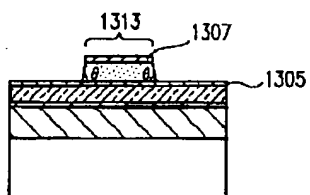


[Drawing 13]

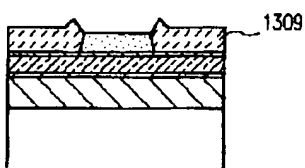
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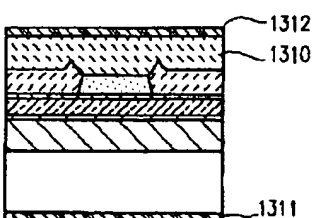
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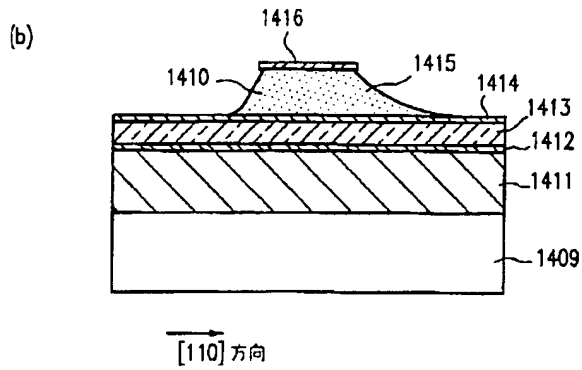
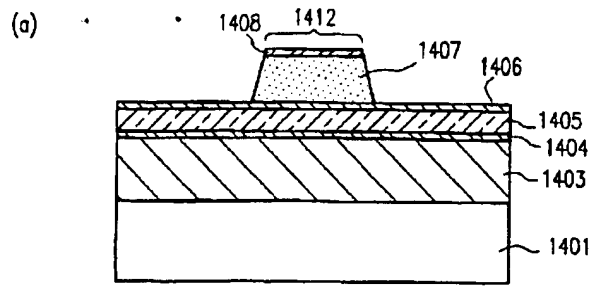
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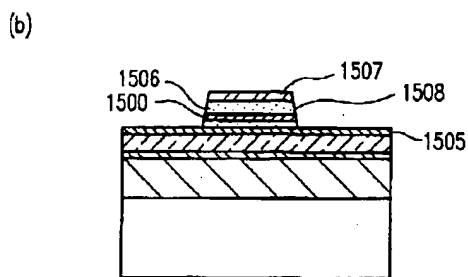
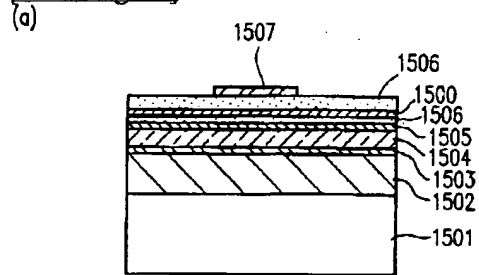
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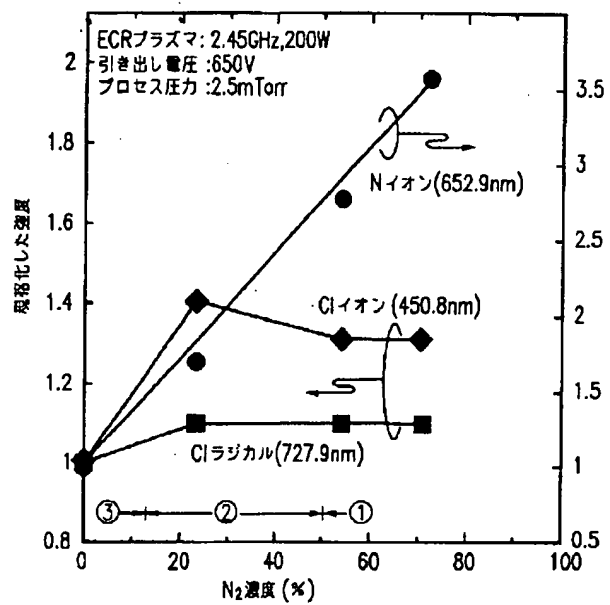
[Drawing 14]



[Drawing 15]



[Drawing 16]



[Translation done.]

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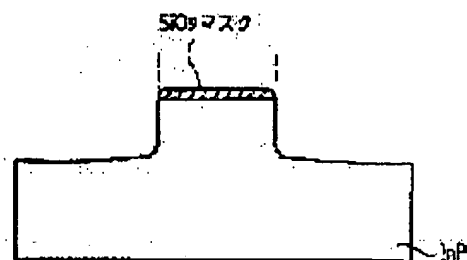
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(54) ETCHING OF COMPOUND SEMICONDUCTOR, SEMICONDUCTOR LASER ELEMENT,
AND MANUFACTURE THEREOF

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a method for
dry-etching a compound semiconductor to form a
vertical, smooth etched surface thereof.SOLUTION: In the etching method, a dry etching
apparatus having a plasma generation source for
generating plasma having a density of about 10^{10}cm^{-3}
or more is used to subject a family III-V compound
semiconductor or a family II-VI compound
semiconductor to a dry etching process with use of a
mixture of a gas containing halogen elements and a
nitrogen gas. At this time, it is set to approximately
satisfy a relationship of (flow rate of a gas containing
halogen elements)/(flow rate of nitrogen gas) ≥ 1 , and a
pressure in the etching reaction is set at about 1mTorr
or more.

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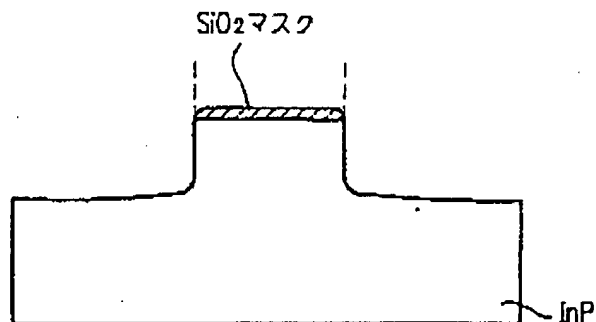
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(54) 【発明の名称】 化合物半導体のエッチング方法、半導体レーザー素子およびその製造方法

(57) 【要約】

【課題】 化合物半導体のドライエッチングにおいて、垂直で平滑なエッチング面を形成する方法を提供する。

【解決手段】 本発明によるエッチング方法は、約10¹⁰ cm⁻³以上の密度のプラズマを発生するプラズマ源を備えたドライエッチング装置によって、ハロゲン元素を含むガスと窒素ガスとの混合ガスを用いて、III-V族化合物半導体またはII-VI族化合物半導体をドライエッチングするエッチング方法であって、(ハロゲン元素を含むガスの流量)/(窒素ガスの流量) ≥ 1程度であり、エッチング反応中の圧力は、約1 mTorrまたは1 mTorr以上である。

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【特許請求の範囲】

【請求項1】 約 $1 \times 10^{10} \text{ cm}^{-3}$ 以上の密度のプラズマを発生するプラズマ源を備えたドライエッチング装置によって、ハロゲン元素を含むガスと窒素ガスとの混合ガスを用いて、III-V族化合物半導体またはII-VI族化合物半導体をドライエッチングするエッチング方法であって、（ハロゲン元素を含むガスの流量）／（窒素ガスの流量） ≥ 1 程度であり、

エッチング反応中の圧力は、約1mTorrまたは1mTorr以上である、エッチング方法。

【請求項2】 前記プラズマ源で発生したイオンを加速し、加速された該イオンの運動エネルギーにより、試料表面を加熱しながらエッチングする、請求項1に記載のエッチング方法。

【請求項3】 前記プラズマ源で発生したイオンを加速し、加速された該イオンの運動エネルギーにより、II-VI族化合物を含む試料の表面近傍のみを加熱し、該試料の支持台を冷却する、請求項1に記載のエッチング方法。

【請求項4】 試料支持台を加熱しながらエッチングする、請求項1に記載のエッチング方法。

【請求項5】 前記プラズマ源で発生したイオンを第1の加速電圧で加速して、エッチングする第1のドライエッチング工程と、

該第1のドライエッチング工程の後に行い、該プラズマ源で発生したイオンを第2の加速電圧で加速して、エッチングする第2のドライエッチング工程と、をさらに包含しており、該第1の加速電圧は、該第2の加速電圧より大きい請求項1に記載のエッチング方法。

【請求項6】 請求項1に記載のドライエッチングを行う第1のエッチング工程と、湿式エッチングを行う第2のエッチング工程と、を包含する請求項1に記載のエッチング方法。

【請求項7】 前記ドライエッチング装置は、ラジカルビーム源とイオンビーム源とを備えており、該ラジカルビーム源によって発生するラジカルの密度と、該イオンビーム源によって発生するイオンの密度と、をそれぞれ独立に制御しながらドライエッチングを行う、請求項1に記載のエッチング方法。

【請求項8】 前記化合物半導体は、 $\text{Al}_x\text{Ga}_y\text{In}_{1-x-y}\text{P}$ ($0 < x \leq 1$ 、 $0 \leq y \leq 1$) によって形成されている、請求項1に記載のエッチング方法。

【請求項9】 前記化合物半導体は、オフ基板上に形成されている請求項8に記載のエッチング方法。

【請求項10】 約 $1 \times 10^{10} \text{ cm}^{-3}$ 以上の密度のプラズマを発生するプラズマ源を備えたドライエッチング装置によって、ハロゲン元素を含むガスと窒素ガスとの混合ガスを用いて、III-V族化合物半導体またはII-VI族化合物半導体をドライエッチングするエッチング方法であっ

ハロゲンイオン密度をハロゲンラジカル密度より大きくして、エッチングする第1のドライエッチング工程と、ハロゲンイオン密度をハロゲンラジカル密度より小さくして、エッチングする第2のドライエッチング工程と、を包含するエッチング方法。

【請求項11】 ラジカルビーム源と、イオンビーム源と、該ラジカルビーム源および該イオンビーム源と接続した反応室と、該反応室内に設けられた試料支持台と、ロードロック室とを備えたエッチング装置。

【請求項12】 半導体基板上に、少なくとも1つの化合物半導体層をエピタキシャル成長する工程と、該少なくとも1つの化合物半導体層上に、パターニングされたマスクを形成する工程と、

該マスクを用いて、該少なくとも1つの化合物半導体層に対して、請求項1～10のいずれかに記載のエッチング方法を用いてエッチングを行い、リジストライブを形成する工程と、

該リジストライブを化合物半導体で埋め込む工程と、を包含する半導体レーザ素子の製造方法。

【請求項13】 前記基板は、傾斜基板であり、

前記少なくとも1つの化合物半導体層は、活性層と、該活性層を挟むn型AlGaInPクラッド層とp型AlGaInPクラッド層とを含んでおり、

前記リジストライブは、該p型AlGaInP層を含んでいる、クレーム12に記載の半導体レーザ素子の製造方法。

【請求項14】 前記p型AlGaInPクラッド層は、p型AlGaInP第1のクラッド層と、p型AlGaInP第2のクラッド層とを有しており、該第1のクラッド層と該第2のクラッド層との間に、エッチングストップ層が形成されている、請求項13に記載の半導体レーザ素子の製造方法。

【請求項15】 前記p型AlGaInP第2のクラッド層の中には、該第2のクラッド層がエッチングされた量をモニタするための層が形成されている、請求項14に記載の半導体レーザ素子の製造方法。

【請求項16】 基板と、

該基板上に設けられており、活性層と、該活性層を挟むn型クラッド層とp型クラッド層と、を含むリジストライブと、を備えた半導体レーザ素子であって、

該リジストライブは、レーザ発振するレーザ部とテーパー状の先端部とを有し、

該リジストライブの底面と、該リジストライブの側面となす角度は、約 60° 以上 90° 以下である、半導体レーザ素子。

【請求項17】 傾斜基板と、

該基板上に形成された、n型AlGaInPクラッド層、活性層、およびp型AlGaInPクラッド層と、を備えた半導体レーザ素子であって、

前記n型AlGaInPクラッド層は、活性層の両側に形成され、

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を持ったリッジ構造を有し、該リッジ構造の両側には、電流ブロック層が形成されている、半導体レーザ素子。

【請求項18】 前記p型AlGaInPクラッド層は、p型AlGaInP第1のクラッド層と、p型AlGaInP第2のクラッド層とを有しており、該第1のクラッド層と該第2のクラッド層との間に、エッチングストップ層が形成されている、請求項17に記載の半導体レーザ素子。

【請求項19】 前記p型AlGaInP第2のクラッド層の中には、該第2のクラッド層のエッチングされた量をモニタするための層が形成されている、請求項18に記載の半導体レーザ素子。

【請求項20】 前記先端部は、前記レーザ部の幅よりテーパ状に狭くなる幅を有する、該幅は約1 μm 以下である、請求項16に記載の半導体レーザ素子。

【請求項21】 前記先端部は、前記レーザ部の幅よりテーパ状に広くなる幅を有する、請求項16に記載の半導体レーザ素子。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】 本発明は、化合物半導体、特にIII-V族またはII-VI族化合物半導体のドライエッチング方法、及びそれを用いて作製された半導体レーザ素子に関する。

【0002】

【従来の技術】 従来の化合物半導体のドライエッチング技術として、例えば、特開平7-66175号公報に記載されている方法がある。この方法では、複合磁場型ECR-RIBE（電子サイクロトロン共鳴-反応性イオンビームエッチング）装置を用いて、In系化合物半導体に対してドライエッチングを行う。複合磁場型ECR-RIBE装置では、主コイルと副コイルの2つの機能のコイルが備えられており、エッチングする試料付近での磁場の発散が抑えられる。この方法によると、エッチングガスとしては、塩素と窒素が用いられる。塩素ガス/窒素ガスの流量比が1以下、内圧が0.5mTorrの条件で、エッチングマスクに対して、垂直な断面および平滑なエッチング面が得られる。

【0003】 上記公報によると、塩素ガス/窒素ガスを1以下の割合でガスを供給する場合、塩素ラジカルの発生が抑制され、塩素ラジカルより塩素イオンによるエッチングが優勢となる。このため、10数eVの低いエネルギーを有するイオンを用いても、Inの塩化物とPの塩化物の蒸発のバランスをとることができる。この結果、エッチングマスクに対して垂直な断面、および平滑なエッチング面が得られるエッチングが実現できる。

【0004】

【発明が解決しようとする課題】 従来、化合物半導体のドライエッチングにおいて、III族元素とエッチングガスの反応物の蒸気圧の差が大きいことに起因するエッチング面の荒れや、断面形状の制御が困難等の問題があった。

【0005】 上記特開平7-66175号公報に開示されるドライエッチング技術も、この問題を解決するためのものである。この技術では、窒素ガスの添加により、塩素ガスが分解して、生成される塩素イオンと塩素ラジカルのうち、塩素ラジカルの生成量は、1/3程度にまで抑制されている。このことによって、上記問題を解決している。また、上記技術では、塩素ラジカルの生成量を最小にするため、反応室内の圧力を0.5mTorr以下にしている。この結果、Inの塩化物とPの塩化物の脱離速度が均衡になる。上記技術の特徴は、塩素ラジカル濃度が最小になる条件でエッチングを行うことである。上記公報は、塩素イオンの生成量とエッチング特性についての定量的なデータを示していない。

【0006】 また、エッチングする試料にAlが含まれている場合、反応室内の残留水分によりAl₂O₃が形成されることで、エッチングされなくなるか、エッチングレートが大きく低下する問題がある。

【0007】 本発明は、上記事情に鑑みてなされたものであって、その目的とするところは、III-V族及びII-VI族化合物半導体、さらにAlを含んでいるIII-V族化合物半導体に対して、窒素ガスを添加した塩素ガスをを用いて、塩素ガスラジカル生成量を低減させることなく、垂直な断面および平滑なエッチング面が得られるドライエッチング方法を提供し、また、このドライエッチング方法を用いて作製された半導体レーザ素子およびその製造方法を提供することにある。

【0008】

【課題を解決するための手段】 本発明によるエッチング方法は、約10¹⁰cm⁻³以上の密度のプラズマを発生するプラズマ源を備えたドライエッチング装置によって、ハロゲン元素を含むガスと窒素ガスとの混合ガスをを用いて、III-V族化合物半導体またはII-VI族化合物半導体をドライエッチングするエッチング方法であって、（ハロゲン元素を含むガスの流量）/（窒素ガスの流量） ≥ 1 程度であり、エッチング反応中の圧力は、約1mTorrまたは1mTorr以上であり、そのことにより上記目的が達成される。

【0009】 ある実施形態では、上記ドライエッチングを行う第1のエッチング工程と、湿式エッチングを行う第2のエッチング工程とを包含する。

【0010】 ある実施形態では、前記プラズマ源で発生したイオンを加速し、加速された該イオンの運動エネルギーにより、試料表面を加熱しながらエッチングする。

【0011】 ある実施形態では、前記プラズマ源で発生したイオンを加速し、加速された該イオンの運動エネルギーにより、II-VI族化合物を含む試料の表面近傍の材料を加熱し、試料の表面近傍の材料を加熱する。

【0012】ある実施形態では、試料支持台を加熱しながらエッチングする。

【0013】ある実施形態では、前記プラズマ源で発生したイオンを第1の加速電圧で加速して、エッチングする第1のドライエッチング工程と、該第1のドライエッチング工程の後に行い、該プラズマ源で発生したイオンを第2の加速電圧で加速して、エッチングする第2のドライエッチング工程と、をさらに包含しており、該第1の加速電圧は、該第2の加速電圧より大きい。

【0014】ある実施形態では、前記ドライエッチング装置は、ラジカルビーム源とイオンビーム源とを備えており、該ラジカルビーム源によって発生するラジカルの密度と、該イオンビーム源によって発生するイオンの密度と、をそれぞれ独立に制御しながらドライエッチングを行う。

【0015】ある実施形態では、前記化合物半導体は、 $\text{Al}_x\text{Ga}_{1-x}\text{In}_y\text{P}$ ($0 < x \leq 1$, $0 \leq y \leq 1$) によって形成されている。

【0016】ある実施形態では、前記化合物半導体は、オフ基板上に形成されている。

【0017】本発明による他のエッチング方法は、約 10^{10}cm^{-3} 以上の密度のプラズマを発生するプラズマ源を備えたドライエッチング装置によって、ハロゲン元素を含むガスと窒素ガスとの混合ガスを用いて、III-V族化合物半導体またはII-VI族化合物半導体をドライエッチングするエッチング方法であって、ハロゲンイオン密度をハロゲンラジカル密度より大きくして、エッチングする第1のドライエッチング工程と、ハロゲンイオン密度をハロゲンラジカル密度より小さくして、エッチングする第2のドライエッチング工程とを包含しており、そのことにより上記目的が達成される。

【0018】本発明によるエッチング装置は、ラジカルビーム源と、イオンビーム源と、該ラジカルビーム源および該イオンビーム源と接続した反応室と、該反応室内に設けられた試料支持台と、ロードロック室とを備えており、そのことにより上記目的が達成される。

【0019】本発明による半導体レーザ素子の製造方法は、半導体基板上に、少なくとも1つの化合物半導体層をエピタキシャル成長する工程と、該少なくとも1つの化合物半導体層上に、パターンニングされたマスクを形成する工程と、該マスクを用いて、該少なくとも1つの化合物半導体層に対して、請求項1~10のいずれかに記載のエッチング方法を用いてエッチングを行い、リッジストライプを形成する工程と、該リッジストライプを化合物半導体で埋め込む工程と、を包含しており、そのことにより上記目的が達成される。

【0020】ある実施形態では、前記基板は、傾斜基板であり、前記少なくとも1つの化合物半導体層は、活性層と、該活性層を挟むn型AlGaInPクラッド層と、p型AlGaInPクラッド層とを含んでおり、前記リ

ッジストライプは、該p型AlGaInP層を含んでいる。

【0021】ある実施形態では、前記p型AlGaInPクラッド層は、p型AlGaInP第1のクラッド層と、p型AlGaInP第2のクラッド層とを有しており、該第1のクラッド層と該第2のクラッド層との間に、エッチングストップ層が形成されている。

【0022】ある実施形態では、前記p型AlGaInP第2のクラッド層の中には、該第2のクラッド層がエッチングされた量をモニタするための層が形成されている。

【0023】本発明による半導体レーザ素子は、基板と、該基板上に設けられており、活性層と、該活性層を挟むn型クラッド層とp型クラッド層と、を含むリッジストライプと、を備えた半導体レーザ素子であって、該リッジストライプは、レーザ発振するレーザ部と、先端部とを有し、該リッジストライプの底面と、該リッジストライプの側面となす角度は、約 60° 以上 90° 以下であり、そのことにより上記目的が達成される。

【0024】ある実施形態では、前記先端部は、前記レーザ部の幅よりテーパ状に細くなる幅を有しており、該幅は約 $1 \mu\text{m}$ 以下である。

【0025】ある実施形態では、前記先端部は、前記レーザ部の幅よりテーパ状に広くなる幅を有する。

【0026】本発明による他の半導体レーザ素子は、傾斜基板と、該基板上に形成された、n型AlGaInPクラッド層、活性層、およびp型AlGaInPクラッド層と、を備えた半導体レーザ素子であって、該p型AlGaInPクラッド層は、ほぼ対称的な形状を持ったリッジ構造を有し、該リッジ構造の両側には、電流ブロック層が形成されており、そのことにより上記目的が達成される。

【0027】ある実施形態では、前記p型AlGaInPクラッド層は、p型AlGaInP第1のクラッド層と、p型AlGaInP第2のクラッド層とを有しており、該第1のクラッド層と該第2のクラッド層との間に、エッチングストップ層が形成されている。

【0028】ある実施形態では、前記p型AlGaInP第2のクラッド層の中には、該第2のクラッド層のエッチングされた量をモニタするための層が形成されている。

【0029】

【発明の実施の形態】以下に、本発明の実施形態を詳細に説明する。

【0030】(第1の実施形態) 本発明によるドライエッチング方法の第1の実施形態として、III-V族化合物半導体に対するドライエッチング方法を説明する。エッチングする試料として、InPが用いられる。エッチングガスとして、塩素ガスと窒素ガスを用いる。図1は、本実施形態で用いられる反応室の概略図である。

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子サイクロトロン共鳴-反応性イオンビームエッチング、以下、ECR-RIBE装置と略称する)の構成を模式的に示す。この装置において、エッチングする試料の位置が、磁場を発生するコイルの外側にある。

【0031】図1に示されるように、ECR-RIBE装置は、主に、ECR源101と、ECR源につながっており、試料を設置するための反応室102と、排気ポンプ系(図示せず)とを備えている。ECR源101では、イオン及びラジカルが生成される。ガス導入口108から、流量が制御された塩素ガスおよび窒素ガスが、ECR源101に導入される。さらに、導波管106から、2.45GHzのマイクロ波が、石英窓107に面して、ECR源101に導入され、塩素ガスおよび窒素ガスは励起状態になる。電子は、コイル103で発生した875ガウスの磁場に共鳴し、円運動をしながらガスと衝突を繰り返す。こうして、ECR源101で発生した塩素イオンおよび窒素イオンは、グリッド104で加速されて、試料105に照射される。

【0032】塩素イオンと窒素イオンは加速されて試料105に照射されるが、ECR源101で発生する塩素ラジカルと窒素ラジカルは、イオン化されていないので、加速されない。しかし、塩素ラジカルと窒素ラジカルは、拡散により試料105の表面に到達し、エッチン

グに寄与する。このECR-RIBE装置は、複合磁場型とは異なり、反応室102の側面には、コイルが設置されていない。このため、コイル103で発生する磁場は、発散磁場である。

【0033】上述のように生じたイオン及びラジカルは、試料105表面に到達し、試料であるInPと反応して、In塩化物とP塩化物が生成する。P塩化物は、PCl₃の沸点が76℃、PCl₅の沸点が162℃と低く、容易に気化する。

【0034】一方、In塩化物は、InClの沸点が608℃、InCl₂の沸点が560℃、InCl₃の沸点が600℃と高く、気化しにくい。このため、試料105の表面には、In塩化物の層が形成される。ECR源101から、加速された塩素イオンおよび窒素イオンが試料105の表面に衝突することで、In塩化物の気化は促進されるので、イオンの加速電圧が重要な要素となる。加速電圧300V以下では、In塩化物は、気化が起こらずエッチングされない。

【0035】表1は、本実施形態で用いられるエッチングの条件を示す。

【0036】

【表1】

塩素	窒素	マイクロ波パワー	加速電圧	内圧	試料温度
3~20 SCCM	3.5~35 SCCM	200W(固定)	300~900 V	0.5~2.5 mTorr	室温 ~300℃

【0037】表1に示される条件において、加速電圧が約300V以上で、エッチングが最適である。なお、エッチングのためのマスクとして、SiO₂を使用している。

【0038】以下に、表1に示される条件を用いて、ドライエッチングを行った主な結果を説明する。

【0039】実験では、塩素流量を約10SCCM、加速電圧を約650V、反応中の内圧を約2.5mTorr、試料温度を約200℃に設定し、窒素流量を変化させてドライエッチングを行った。試料支持台を加熱し、試料温度を200℃程度に維持することによって、III族化合物の蒸発を促進できる。

【0040】窒素流量として、図2は約3.5SCCM、図3は約7SCCM、図4は約3.5SCCMの条件でドライエッチングを行ったInPのそれぞれの断面写真を模式図に示す。

【0041】図2(a)は、InP基板に対して、SiO₂マスクを用いてエッチングした断面を示す。この図から分かるように、InPはエッチングされているが、底面(エッチング面)が非常に荒れている。図2(b)は、図2(a)の斜視図である。図2(b)からも、底面が荒れていることがよくわかる。図3の場合、SiO₂

おり、また、底面荒れも殆どなくなっている。図4の場合、底面荒れはなく、エッチング面は平滑である。ただし、マスクの下側もエッチングされるサイドエッチングが起こり、マスクに対して、垂直なエッチングはできていない。

【0042】上記結果から、塩素流量/窒素流量が約0.29から1.43の間に、エッチング面が荒れるか否かの境界があることがわかる。実験によると、その境界の塩素流量/窒素流量の比は、約1.0付近であることがわかった。また、塩素流量/窒素流量の比が約2.85付近で、エッチング面の平滑性が一番よいことがわかる。

【0043】しかしながら、図4の断面形状を見ると、垂直でなく、サイドエッチングがかなり入っている。垂直な断面を得るためには、ドライエッチングにおける化学反応成分を抑える必要がある。そこで、試料温度を約100℃に下げてエッチングを行った。その結果は、図5に示される(温度以外の条件は図4の場合と同じである)。

【0044】試料温度を100℃に下げることにより、化学反応性よりスパッタ成分が強くなり、SiO₂マス

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動)してしまう。このため、オーバーエッチングが起こり、台形の断面形状になる。ただし、エッチング面が非常に平滑であるので、台形の断面でも実用上問題は無い。

【0045】図4および5から分かるように、エッチングにおける化学反応成分がスパッタ成分より優勢である場合に、サイドエッチが起こり、スパッタ成分が化学反応性より優勢である場合には、マスクが後退して、オーバーエッチが起こる。

【0046】次に、垂直な断面を得るためのエッチング条件の検討について説明する。

【0047】化学反応性を増加させるために試料温度を

約150℃にし、エッチングレートを向上させるために塩素の供給量を約11.5 SCCMまで増やして(窒素流量は図4の場合と同じく3.5 SCCM)、エッチングを行った。その結果は、図6に示される。図6から分かるように、スパッタ成分と化学反応成分のバランスがとれ、垂直なエッチング断面が実現される。この場合、加速電圧は約650V、内圧は約2.5mTorrのままである。

【0048】図2～6の場合のそれぞれのエッチング条件は、まとめて表2に示す。

【0049】

【表2】

	塩素 (SCCM)	窒素 (SCCM)	塩素/窒素 流量比	加速電圧 (V)	内圧 (mTorr)	試料温度 (℃)
図2	10	35	0.29	650	2.5	200
図3	10	7	1.43	650	2.5	200
図4	10	3.5	2.8	650	2.5	200
図5	10	3.5	2.8	650	2.5	100
図6	11.5	3.5	3.29	650	2.5	150

【0050】塩素流量/窒素流量の比が約1.0以上であれば、エッチング面は荒れない。しかし、この流量比を6.4以上に大きくすると、エッチング面は、また少し荒れ始める。エッチング面の荒れを考慮して、塩素流量/窒素流量の流量比の最適値は、約1.0～6.4の範囲である。

【0051】図16は、プラズマ発光の分光結果を示す。この分光結果は、窒素濃度に対する窒素イオン、塩素イオン、および塩素ラジカルの強度変化を表す。図16に示される各発光強度は、塩素ガスのみのプラズマ発光強度で規格化されている。窒素イオンは652.9nm、塩素イオンは450.8nm、塩素ラジカルは727.9nmでの発光が観測された。塩素ガスのみの場合の652.9nmでの発光は、雑音であり、窒素イオンによる発光ではない。

【0052】窒素イオンの発光強度は、窒素の添加量に比例して単純に増加する。塩素イオンによる発光強度は、窒素の添加によって増加するが、窒素の添加濃度が約23%で最大値を示す。この最大値は、窒素無添加の場合の約1.4倍である。その後、窒素添加濃度の増加に従って、塩素イオンによる発光強度は、少し減少し、窒素無添加の場合の約1.3倍の値で飽和する。塩素ラジカルによる発光強度は、窒素の添加によって、約10%増加するが、この程度で飽和し、さらに窒素を添加しても増加しない。

【0053】以下に、上記発光強度の変化を、エッチング特性と比較して説明する。

【0054】塩素流量/窒素流量が1未満の場合は、図16での窒素濃度が50%を超える領域(領域①)であ

て、塩素イオン強度は約1.3倍以上になっているが、窒素イオン強度は約3倍になっている。つまり、過剰な窒素イオンにより、In塩化物及びP塩化物のうち、蒸気圧の高いP塩化物が選択的にスパッタされることによって、エッチング面が荒れると考えられる。

【0055】塩素流量/窒素流量が約1以上6.4以下の場合、図16の窒素濃度が約13%以上約50%以下の領域(領域②)に相当する。この領域では、窒素イオンの強度は、それほど増加しておらず、In塩化物及びP塩化物の表面からの脱離の均衡がとれ、平滑なエッチング面が実現されている。

【0056】塩素流量/窒素流量が6.4を超える場合は、図16の窒素濃度が約13%以下の領域(領域③)に相当する。領域③の場合、再びエッチング面が荒れる。これは、生成したIn塩化物及びP塩化物の脱離はスパッタ効果より主に熱エネルギーにより起こるため、P塩化物の選択的な脱離が起こるからであると考えられる。

【0057】以上述べたように、本発明において、窒素ガスを添加する効果は、塩素イオンの生成を促進するだけでなく、窒素イオン自体によるスパッタ効果によって、III族あるいはV族の塩化物の脱離を促進するところに大きな特徴がある。これは、II-VI族化合物半導体に本発明を適用した場合にも、同様である。

【0058】以上の説明では、エッチングする材料として、III-V族化合物半導体のInPを用いたが、後で説明するように、InPの代わりに、AlGaInP系、AlGaInN系、また、II-VI族化合物半導体のZnMgSSe系の材料を用いてもよい。また、エッチ

エッチングは可能である。

【0059】（第2の実施形態）以下に、本発明によるドライエッチング方法の第2の実施形態として、III-V族化合物半導体に対するドライエッチング方法を説明する。より具体的には、試料全体の温度を上昇させることなく、加速されたイオンの運動エネルギーにより、試料表面のみを加熱しながら、エッチングするドライエッチング方法を説明する。

【0060】エッチング試料としてInPが用いられ、エッチングマスクとしてSiO₂が用いられる。なお、本実施形態の方法は、II-VI族化合物半導体のエッチングに適用できる。

【0061】上記第1の実施形態で述べたように、試料温度を上昇させる場合、ドライエッチングにおける化学反応成分がスパッタ成分より優勢になり、マスクの下側もエッチングされるサイドエッチングが起こる。ところが、試料温度を下げると、スパッタ成分が強くなるので、マスクが後退するオーバーエッチを起こしたり、エッチング底面が荒れたりする。

【0062】そこで、本実施形態では、試料をA1で作製した試料保持治具に密着させ、この保持治具を冷却しながらエッチングする。

【0063】ECR源で発生するイオンは、グリッドで数百Vで加速され、運動エネルギーを持って試料に照射される。ECR源で発生するラジカルは、加速されない。ラジカル1個当たりのエネルギーは、20~30eVと小さいが、発生するラジカル数が多いため、試料表面がラジカルから受け取る全エネルギーは、かなり大きい。このように、試料表面が多数のイオン、ラジカルのエネルギーを得るため、試料基板の温度を上昇しなくとも、試料自体を数百℃まで上昇させた場合と同様な効果が得られる。すなわち、このように試料の表面を加熱することによって、III族またはII族の塩化物の蒸発を促進し、エッチングレートを向上する。

【0064】図8は、ECR-RIBE装置を使用し、塩素流量を約11.5SCCM、窒素流量を約3.5SCCM、マイクロ波パワーを約200W、内圧を約2.5mTorr、加速電圧を約650Vにして、InPに対してドライエッチングを行った場合のInPの断面を示す。

【0065】この場合、試料全体に対して、加熱していない。試料は、A1で作製した試料保持治具に装着されている。試料保持治具は、水冷された試料支持台に載せられる。このことによって、試料の表面近傍の部分だけが加熱され、この部分を除いた部分の温度は、上昇しない。試料は、熱的ダメージから保護される。こうすることは、特にII-VI族化合物を含む試料をエッチングするのに有効である。なぜなら、II-VI族化合物半導体の結晶成長温度（約260℃）が低いため、結晶性の劣化を防止するためには、エッチング温度を結晶成長温度より低い（約250℃以下）にする必要がある。

【0066】上記第1の実施形態で述べたように、エッチング断面の形状は、エッチングするスパッタ成分と化学反応成分のバランスを反映する。すなわち、スパッタ成分が優勢の場合に断面はオーバーエッチされ、化学反応成分が優勢の場合にはサイドエッチングが起こる。

【0067】図8から分かるように、本実施形態によると、試料全体の温度が室温付近であるにも関わらず、断面はほぼ垂直であり、化学反応成分とスパッタ成分のバランスがとれている。図8の断面は、試料温度を150℃に設定してエッチングを行った場合、すなわち、図6の場合と同じ断面形状を示す。つまり、加熱せずにエッチングを行った図8に示される結果は、断面形状に関して、試料温度を150℃に設定してエッチングを行った図6に示される結果と同じである。ただし、図8の場合のエッチングレートは、図6の場合のそれより25%低い。

【0068】なお、本実施形態では、試料温度は室温付近に設定されているが、試料支持台を0℃以下に冷却して、V族の塩化物の昇華を抑制することにより、III族の塩化物との昇華の差を小さくすることもできる。このことによって、垂直な断面、および平滑なエッチング面が得られるドライエッチングを行うことができる。

【0069】（第3の実施形態）本発明によるドライエッチング方法の第3の実施形態として、III-V族化合物半導体に対するドライエッチング方法を説明する。より具体的には、異なる条件の2段階のエッチングを行うドライエッチング方法を説明する。試料としてInP、エッチングマスクとしてSiO₂、エッチングガスとして塩素と窒素を用いる。

【0070】ECR-RIBE装置を用い、まず、第1のドライエッチングを行う。この第1のドライエッチングにおいては、内圧を約1mTorr以下、加速電圧を約300V以上にすることでガス分子間の衝突を抑え、ラジカル密度よりもイオン密度を大きくする。塩素流量/窒素流量は約1以上、試料温度は約100℃に設定される。この場合、化学反応成分よりスパッタ成分によるエッチングが優勢になり、試料表面に対して垂直な方向における高速なドライエッチングが進み、所望の形状に近い形状が形成される。

【0071】上記第1のドライエッチングは、約1000A/分以上と比較的高いエッチングレートを有する。高速でエッチングを行う場合、エッチングされた側面またはエッチング面において、加工に誘起される損傷が生じたり、エッチング面が荒れたりする。これは、ECR源で発生するハロゲンイオンが300V以上の高い電圧で加速され試料に照射されることによって、試料に結晶欠陥が生じるからである。また、ハロゲン化合物の沸点がIII族（またはII族）とV族（またはVI族）で異なるため、エッチング面におけるストイキオメトリがずれることによって、エッチング面におけるIII族（またはII族）元素の濃度が（またはII族）元素より高くなるかたがたである。

る。

【0072】次に、第1のドライエッチングに引き続き、第2のドライエッチングを行う。この第2のドライエッチングを行う目的としては、第1のドライエッチングにより生じた加工誘起損傷を持つ層を除去することである。また、第1のドライエッチングで、エッチング面に荒れが生じた場合に、荒れた面を除去して平滑にすることである。上記目的を達成するために、第2のドライエッチングは、塩素流量/窒素流量を約3以上、内圧を約2mTorr以上、加速電圧を約300V以下、試料温度を約200℃に設定して行う。この場合、ガス分子間の衝突が増え、イオン密度よりラジカル密度のほうが大きくなる。さらに、平均自由行程が小さくなるので、スパッタ成分より化学反応成分のほうが強く作用する。

【0073】上記のような化学反応性の強い条件下でのエッチングは、結晶に与える加工誘起損傷が小さいので、第1のドライエッチングで生じた加工誘起損傷を多く含んだ層を除去することができる。第1のドライエッチングでエッチング面が荒れた場合、上記第2のドライエッチングにより、荒れた面をより平滑にすることができる。

【0074】第1のドライエッチングは、塩素流量/窒素流量約 ≥ 1 、内圧約 ≤ 1 mTorr、加速電圧約 ≥ 300 Vの条件で行うことができるが、最適条件として、塩素流量/窒素流量約 ≥ 3 、内圧約 ≤ 0.5 mTorr、加速電圧約 ≥ 600 Vの方がより望ましい。

【0075】第2のドライエッチングは、塩素流量/窒素流量約 ≥ 3 、内圧約 ≥ 2 mTorr、加速電圧約 ≤ 300 Vの条件で行うことができるが、最適条件として、塩素流量/窒素流量約 ≥ 10 、内圧約 ≥ 3 mTorr、加速電圧約 ≤ 100 Vの方がより望ましい。

【0076】図12は、本実施形態によるドライエッチングの工程を示す断面図である。まず、図12(a)に示されるように、InP基板1201上に、パターニングされたSiO₂マスク1202を形成する。その後、図12(b)に示されるように、第1のドライエッチングを行う。この工程によって、加工に誘起される損傷層1203がエッチング表面に生じる。次に、図12(c)に示されるように、第2のドライエッチングを行う。第2のドライエッチングにおいて、第1のドライエッチングの場合より、塩素イオン密度が小さく、塩素ラジカル密度が大きい。第2のドライエッチングを行うことによって、加工に誘起される損傷層1203が除去され、マスク1202に対して垂直な側面、平滑なエッチング面が形成できる。

【0077】なお、以上の説明では、内圧、流量比及び加速電圧を変えることによって、第1および第2のドライエッチングにおける塩素イオン密度と塩素ラジカル密度との大小関係を変えた。この代わり、加速電圧のみを

行ってもよい。すなわち、第1、第2のドライエッチングとも、塩素流量/窒素流量約 ≥ 3 、内圧約 ≥ 2 mTorr、試料温度約200℃の条件を用い、第1のドライエッチングでは加速電圧を約900V、第2のドライエッチングでは加速電圧を約100Vに設定する。このような条件で、ドライエッチングを行っても、荒れのないエッチングが実現できる。

【0078】(第4の実施形態)以下に、本発明によるエッチング方法の第4の実施形態として、III-V族化合物半導体に対するエッチング方法を説明する。より具体的には、ドライエッチングとウェットエッチングの2段階のエッチングを行うエッチング方法について説明する。試料としてInP、エッチングマスクとしてSiO₂を、エッチングガスとして塩素と窒素を用いる。ウェットエッチングのエッチング溶液として、塩酸、酢酸、過酸化水素水を用いる。

【0079】まず、ECR-RIBE装置を用い、第1のエッチング(ドライエッチング)を行う。この第1のエッチングにおいて、塩素流量/窒素流量を約 ≥ 1 、内圧を約2mTorr以上、加速電圧を約300V以上、試料温度を約100℃以上にする。第1のエッチングは、上記条件で可能であるが、最適条件は、塩素流量が約11.5SCCM、窒素流量が約3.5SCCM、試料温度が約150℃、加速電圧が約650V、内圧が約2.5mTorrである。このような条件で、試料を所定の形状に加工できる。第1のエッチングで発生する加工誘起損傷を含んだ層は、以下に説明する第2のエッチングにより除去される。

【0080】図7は、第2のエッチングに用いられるスピニング装置の構成を模式的に示す。第2のエッチング、すなわち、ウェットエッチングは、反応室705の中で行われる。上記ドライエッチングされた試料701は、試料保持台702上に設置される。試料保持台702は、試料701を真空チャックで保持し、所定の回転速度で回転する。エッチャントタンク704に所定の温度に維持され保存されている塩酸、酢酸、および過酸化水素水の混合液は、ノズル703から出て、試料701上に流れ落ちる。ノズル703と試料保持台702の中心は一致しており、ノズル703は試料保持台702の中心から、試料保持台の半径方向に所定の距離までの間を往復運動する。ノズル703が、回転する試料701に液を流れ落としながら、半径方向を往復運動することにより、極めて均一なウェットエッチングが行われる。こうして、第1のエッチングで生じた加工に誘起される損傷層が除去される。塩酸、酢酸、過酸化水素水の混合比は3:36:1、混合液の温度は20℃であればよい。

【0081】ウェットエッチングはスパッタ成分を含まないので、ドライエッチングを用いることによって与えられるような多少のダメージも、ウェットエッチングを用いることによって防止できる。このため、さらにエッチング面の平滑性を向上できる

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【0082】本実施形態において、第2のエッチングに使用する溶液として、塩酸、酢酸、および過酸化水素水を用いたが、これに代えて、硫酸、過酸化水素水、および水の混合液、塩酸およびリン酸の混合液、または飽和臭素水およびメタノールの混合液を用いてもよい。要は、第1のエッチングにより生じた加工に誘起され損傷層を除去できる溶液であればよい。

【0083】(第5の実施形態)以下に、ECR源のほかに、ラジカルビーム源およびイオンビーム源を備えたドライエッチング装置、およびそれを用いたドライエッチング方法について説明する。

【0084】図9は、本実施形態のドライエッチング装置の構成を模式的に示す。この装置は、ECR源904、反応室901のほかに、ラジカルビーム源902、およびイオンビーム源903を備えている。ラジカルビーム源902およびイオンビーム源903は、反応室901に接続されている。

【0085】反応室901中には、試料906を保持する試料保持台905が備えられている。ラジカルビーム源902で生成された塩素ラジカル、イオンビーム源903で生成された塩素イオン及びECR源904で生成された塩素イオン、塩素ラジカル、窒素イオンは、試料906に照射される。試料906は、試料906を反応室901に入れるためのロードロック室900から、反応室901に送られる。反応室901は、排気系(図示せず)により約 10^{-6} Torr以下に排気される。

【0086】ラジカルビーム源902では、塩素ガスは、RF高周波が加えられ、プラズマ状態となる。これによって、塩素イオンと塩素ラジカルが発生する。塩素イオンは、加速されない場合、平均自由行程が数センチメートルであるから、ラジカル源902または反応室901の中で他の原子または電子と衝突して消滅するので、試料まで到達しない。生成したラジカルは、拡散により試料表面にまで到達し、反応に寄与する。

【0087】一方、イオンビーム源903でも、塩素ガスは、RF高周波が加えられ、プラズマ状態となる。これによって、塩素イオンと塩素ラジカルが発生する。引き出し電極9031に加える電圧を変化させることにより、イオンビーム源903から引き出される塩素イオンと塩素ラジカルの割合を変えることによって、塩素イオンを塩素ラジカルより多く引き出し、試料表面に照射する。

【0088】ECR源904では、第1の実施形態で述べたように、ガスが分解され、イオンとラジカルが生成される。本実施形態において、窒素ガスをECR源904に導入する。

【0089】上記のようにイオン源、ラジカル源及びECR源を備えることにより、反応に寄与するガスの、平滑性に寄与するラジカルの密度と、エッチングレートに

のため、エッチング面の平滑性を保ったまま、高速なエッチングが可能である。エッチングレート、断面形状、エッチング面の平滑性を制御しやすくなる。 SiO_2 をマスクとして用い、塩素と窒素の混合ガスによるInPのドライエッチングの場合、第1の実施形態で述べたように、P塩化物は容易に昇華し、In塩化物は昇華しにくい。ため、試料表面にIn塩化物の層が形成されることになる。このIn塩化物の層を昇華させるには、加速された塩素イオン及び窒素イオンの運動エネルギーを利用すればよい。

【0090】そこで、塩素イオン流量を塩素ラジカル流量より多くし、塩素イオンと窒素イオンを約300V以上の高電圧で加速して供給すればよい。エッチングレートを高くするためには、試料温度を約150℃以上に設定すればよい。

【0091】本実施形態によると、ラジカルビーム源からの塩素ラジカル流量が約1SCCM以上、イオンビーム源からの塩素イオン流量が約10SCCM以上、加速電圧が約300V以上、ECR源からの窒素イオンが約3SCCM以下で、平滑なエッチング面を持つInPのドライエッチングが可能である。さらに、塩素ラジカル流量が約1SCCM、塩素イオン流量が約10SCCM、塩素イオンの加速電圧が約600V以上、ECR源の窒素流量が約3SCCM、試料温度が約150℃の条件で、垂直な断面と平滑なエッチング面を持つドライエッチングが実現する。

【0092】(第6の実施形態)以下に、上記第1～5の実施形態で説明したエッチング方法を用いて、半導体レーザ素子の製造方法を説明する。半導体レーザ素子として、スポット径変換レーザを用いる。図10(a)～(c)は、スポット径変換レーザの構造の断面を模式的に示す。

【0093】このスポット径変換レーザは、図10(a)に示されるように、レーザ部1010と、スポットサイズ変換部(先端部)1011とを有する。レーザ部1010は、一定の幅と厚さを有するストライプ形状を有する。スポットサイズ変換部1011は、幅が出射端1012に向かって、テーパ状に幅が小さくなっている。レーザ光は、スポットサイズ変換部1011を導波する間に、レーザ部1010におけるスポット径から、スポットサイズ変換部1011の出射端(先端部1011の先端)1012の径mに変換される。出射端1012は、幅mが約 $1\mu\text{m}$ 以下(典型的には、約 $0.6\mu\text{m}$)、断面の角度が約 90° である。

【0094】図10(b)は、図10(a)の線A-A'に沿った断面を示す。図10(b)に示されるように、n-InP基板1001上に順次、n-InP層1002、n-InGaAsPクラッド層1003、活性層1004、p-InGaAsPクラッド層1005、およびp-InPキャップ層1007がエピタキシャル成長されている。これらの層はメサスト

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トライブ1014は半絶縁性InP1006によって埋め込まれている。p-InPキャップ層1007上に、p側電極1009が形成されており、基板1001の全面に、n側電極1008が形成されている。

【0095】p側電極1009から注入された正孔は、n側電極1008から注入された電子と活性層1004で再結合する。発光はp側電極1009の下で起こり、共振器端面で閉じ込められることによって、レーザ発振する。

【0096】図10(c)は、図10(a)の線B-B'に沿った断面を示す。図10(b)と図10(c)を比較して分かるように、レーザ部1010とスポットサイズ変換部1011とでは、活性層1004の幅が異なる。つまり、スポットサイズ変換部1011の活性層1004の幅の方が、小さくなっている。

【0097】以下に、図11(a)～(g)を参照しながら、スポット径変換レーザの製造方法を示す。図11(a)～(g)は、レーザ部1010の断面の模式図である。スポットサイズ変換部1011は、活性層の幅等が異なるだけで、レーザ部1010と同時に製造される。

【0098】まず、図11(a)に示されるように、有機金属気相成長法(MOVPE法)によって、n-InP基板1101上に、n-InP層1102、n-InGaAsPクラッド層1103、活性層1104、p-InGaAsPクラッド層1105を順次成長させる。その後、図11(b)に示されるように、p-InGaAsPクラッド層1105上に、所定の形状を有するSiO₂マスク1106を形成する。

【0099】次に、図11(c)に示されるように、上記第1～5の実施形態で説明したエッチング方法によって、ECR-RIBE装置を用いて、メサストライブ(リッジストライブ)1109を形成する。エッチングの条件は、塩素流量/窒素流量約 ≥ 1 、マイクロ波パワー約200W、内圧約2mTorr以上、試料温度約150°C以上、加速電圧が約300V以上である。この条件で形成されるメサストライブの、側面と基板1101の表面となす角度 θ は、図11(c)および(g)に示されるように、約60°以上90°以下である。次に、図11(d)に示されるように、MOVPE法によって、SiO₂マスク1106を選択成長のマスクとして用いて結晶成長を行い、メサストライブ1109を半絶縁性InP1107で埋め込む。SiO₂マスク1106を除去した後、図11(e)に示されるように、MOVPE法でp-InGaAsPキャップ層1108を成長する。最後に、図11(f)に示されるように、p側電極1111とn側電極1110を蒸着し、熱処理を行いオーミック接触を形成する。

【0100】以上説明したように、本発明によると、ECR-RIBE装置で、塩素ガスと窒素ガスを用いてエッチングを行うことによって、図11(g)に示すよう

あるメサストライブの側壁と、幅約1 μ m以下の出射口を持つキャビティと導波路を形成することができる。本発明の方法によると、素子の信頼性を低下する逆メサ(上記角度 θ が90°以上)が形成されることを回避できる。

【0101】なお、上記説明では、先端部1011の幅は、レーザ部1010の幅よりテーパ状に狭くなっているが、レーザ部1010の幅よりテーパ状に広がってもよい。

【0102】以上の実施形態において、ECR-RIBE装置を用いたが、これに代えて、誘導結合型プラズマ源を備えたドライエッチング装置、ヘリコン型プラズマ源を備えたドライエッチング装置、またはNLD型プラズマ源を備えたドライエッチング装置を用いてもよい。

【0103】また、以上の実施形態で、化合物半導体として、InPを用いて説明したが、他のIII-V族またはI-IV族化合物半導体を用いてもよい。なお、以上の説明では、塩素ガスを用いたが、塩素、臭素、またはヨウ素を含んだガスを用いてもよい。

【0104】(第7の実施形態)以下に、図13(a)～(d)を参照しながら、上記第1～5の実施形態で説明したエッチング方法を用いて、他の半導体レーザ素子の製造方法を説明する。本実施形態において、エッチングされる化合物半導体は、アルミニウム(Al)を含んでいる。

【0105】まず、図13(a)に示されるように、MOVPE法により、n型GaAs基板1301上に、n型GaAsバッファ層(不図示)、n型Al_xGa_{1-x}PyP(0<x \leq 1、0 \leq y \leq 1、以下、AlGaInPと略称する)クラッド層1302、AlGaInP障壁層とGaInP井戸層とによって構成される多重量子井戸活性層1303、p型AlGaInP第1のクラッド層1304、GaInPエッチングストッパ層1305(厚さ:5nm程度)、p型AlGaInP第2のクラッド層1306をエピタキシャル成長させる。GaAs基板1301は、(100)面から[110]方向へ10度程度傾斜しているオフ基板である。

【0106】次に、リッジを形成するために、p型AlGaInP層1306上に、パターニングされた幅約4 μ m、厚さ約0.5 μ mのSiO₂マスク1307を形成する。

【0107】次に、図13(b)に示されるように、上記第1～5で説明したドライエッチング方法を用いて、SiO₂マスク1307をエッチングマスクとして、リッジ1313を形成する。エッチングの条件として、塩素流量を約11SCCM、窒素を約3.5SCCMにすることによって、塩素流量/窒素流量比を、約3.1に設定する。なお、加速電圧は約650V、内圧は約2.5mTorr、試料温度は約100°Cである。このような条件でド

のリッジ1313が得られる。

【0108】通常、傾斜基板を用いるエッチングでは、図14(b)に示すように、リッジは左右対称の形状にならない。基板が(100)面から傾斜しているため、硫酸系のエッチング液を用いるウェットエッチングでは、リッジの底部における側面の傾斜が緩やかとなり、リッジは非対称な形状となる。その結果、活性層へのキャリアの注入および光の閉じ込めが不均一になり、横モードが不安定になる。特に、レーザを高温で動作させるときには、このことは顕著になる。

【0109】また、AlGaInP系の半導体レーザでは、レーザ光の波長を短波長化するためには、傾斜角度をますます大きくしている。傾斜角度が大きくなればなるほど、リッジの非対称性が大きくなる。本実施形態によると、図14(a)に示されるように、上記条件でドライエッチングを行うことによって、オフ基板を用いるにもかかわらず、対称な形状を持ったリッジ1412を形成できる。

【0110】リッジ形成するためのドライエッチングは、図13(b)に示されるように、エッチングストップ層1305で停止させる。ドライエッチングでエッチングされるp型AlGaInP第2クラッド層1306の厚さは、約1.5 μ mである。このような厚い層を、第2の実施形態で説明したように、まず、スパッタ成分の強い第1のドライエッチングで1.3 μ m程度エッチングし、その後、化学反応成分の強い第2のドライエッチングで残りの0.2 μ m程度のp型AlGaInPをエッチングする。こうすれば、エッチングストップ層1305より下の層に、エッチングによるダメージを及ぼすことはない。

【0111】また、第3の実施形態で説明したように、スパッタ成分の強いドライエッチングで、1.3 μ m程度の厚さの第2クラッド層1306をエッチングし、残りの0.2 μ m程度の第2クラッド層1306を、第2のエッチングとして、ウェットエッチングでエッチングしてもよい。

【0112】リッジ1313を形成したあと、図13(c)に示されるように、SiO₂マスク1307をそのまま用いて、n型埋め込み層である、n型GaAs電流ブロック層1309を選択的に成長させる。

【0113】次に、SiO₂マスク1307を除去し、図13(d)に示されるように、p型GaAsコンタクト層1310を成長させる。最後に、n型GaAs基板1301の裏面にn側電極1311、コンタクト層1310上にp側電極1312を形成して、レーザ構造が完成する。

【0114】本実施形態の半導体レーザ素子の製造方法において、リッジ1313の形成に、ハロゲンガスと窒素ガスとの流量比を約1.4 \leq 窒素流量/窒素流量 \leq 約4.0の範囲に設定することにより、リッジ1313の

の底面とリッジ1313の側面となす角度 θ は約60度~90度となるとともに、オフ基板を用いるにもかかわらず、対称性のよいリッジ形状を持つ半導体レーザ素子を製造することができる。このため、活性層へのキャリアの閉じ込め、光の閉じ込めが不均一にならず、横モードが安定な信頼性の高い半導体レーザ素子が得られる。さらに、本実施形態によると、Alを含む化合物半導体のエッチングにもかかわらず、エッチングレートは低下しない。なお、以上の説明では、p型AlGaInP第2クラッド層をドライエッチングする工程において、第1のドライエッチングでAlGaInPクラッド層を1.3 μ m程度エッチングした段階で条件を替え、第2のドライエッチングを行っている。ここで、1.3 μ m程度の厚さのAlGaInPクラッド層がエッチングされたことを容易に検出(モニタ)するために、AlGaInPクラッド層のこの厚さの部分に、図15(a)に示すように、AlGaInP第2クラッド層1506と組成の異なるGaInP層1500(厚さ:10nm程度)を予め挿入していてもよい。

【0115】GaInP層1500を設けることによって、たとえばプラズマからの発光分析をしながらAlGaInP第2クラッド層をエッチングし、エッチングがGaInP層1500までに進行した時点で、GaInP層1500はAlを含んでいないので、発光分析の値が変化する。この変化によって、第2クラッド層が1.3 μ m程度エッチングされたことを正確に検出できる。そして、エッチング条件を替えて、図15(b)に示されるように、第2のドライエッチングを行い、残りの約0.2 μ m厚さの第2クラッド層のをエッチングすればよい。こうすることによって、さらに、エッチング時のダメージが少なく、制御性よく、均一な特性を有する半導体レーザ素子を製造できる。

【0116】本実施形態によると、エッチングする試料にAlが含まれている場合、反応室内の残留水分によりAl₂O₃が形成されても、塩素ラジカル生成量が減少させることなく、塩素イオン生成量を増加することによって、スパッタリングでAl₂O₃の脱離を促進することができる。また、塩素ラジカルとAlとを反応させ、Alは、塩化アルミニウムとなって脱離する。このため、試料がエッチングされなくなるか、エッチングレートが低下する問題は回避できる。

【0117】

【発明の効果】本発明によれば、次のような効果が得られる。

【0118】塩素流量/窒素流量を約1または1以上、内圧を約1mTorrまたは1mTorr以上に保持することにより、平滑なエッチング面を有するIII-V族、およびII-VI族化合物半導体のドライエッチングを行うことができる。

【0119】また、エッチングレートが低下する問題を回避できる。

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たドライエッチング装置を用い、塩素イオン密度と塩素ラジカル密度および窒素イオン密度の量を独立に制御して、ドライエッチングを行うことにより、平滑なエッチング面を有するIII-V族、およびII-VI族化合物半導体のドライエッチングを行うことができる。

【図面の簡単な説明】

【図1】 ECR-RIBE装置の模式図

【図2】 (a) および (b) は、本発明の一実施形態におけるInPのドライエッチング後の断面図

【図3】 本発明の一実施形態におけるInPのドライエッチング後の断面図

【図4】 本発明の一実施形態におけるInPのドライエッチング後の断面図

【図5】 本発明の一実施形態におけるInPのドライエッチング後の断面図

【図6】 本発明の一実施形態におけるInPのドライエッチング後の断面図

【図7】 基板を回転させながら均一にウエットエッチングするためのスピニング装置の構成断面図

【図8】 本発明の一実施形態におけるInPのドライエッチング後の断面図

【図9】 ラジカルビーム源、イオンビーム源及びECR源を備えたドライエッチング装置の構成断面図

【図10】 (a) ~ (c) は、本発明の一実施形態におけるスポット径変換レーザの断面図

【図11】 (a) ~ (g) は、図10のスポット径変換レーザの製造工程断面図

【図12】 (a) ~ (c) は、本発明の一実施形態における異なる条件の2段階ドライエッチングの模式図

【図13】 (a) ~ (d) は、本発明の一実施形態における半導体レーザの製造工程断面図

【図14】 (a) および (b) は、リッジの対称性を比

較する半導体レーザの構成断面図

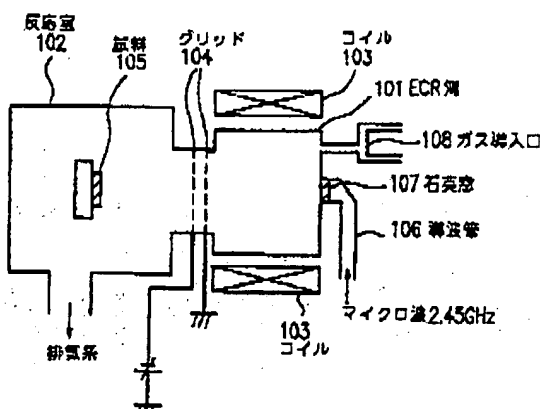
【図15】 (a) および (b) は、クラッド層中にエッチング量のモニタ層を備えた半導体レーザの構成断面図

【図16】 プラズマ発光の分光結果を示す図

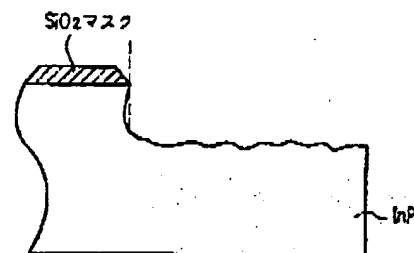
【符号の説明】

- 101 ECR源
- 102 反応室
- 103 コイル
- 104 グリッド
- 105 試料
- 702 試料保持台
- 703 ノズル
- 704 エッチャントタンク
- 705 反応室
- 902 ラジカルビーム源
- 903 イオンビーム源
- 904 ECR源
- 9031 引き出し電極
- 1001 n-InP基板
- 1002 n-InP
- 1003 n-InGaAsPクラッド層
- 1004 活性層
- 1005 p-InGaAsPクラッド層
- 1006 半絶縁性InP
- 1007 p-InPキャップ層
- 1008 n側電極
- 1009 p側電極
- 1010 レーザ
- 1011 スポットサイズ変換部
- 1201 n-InP基板
- 1202 SiO₂マスク
- 1203 加工誘起損傷層

【図1】



【図3】

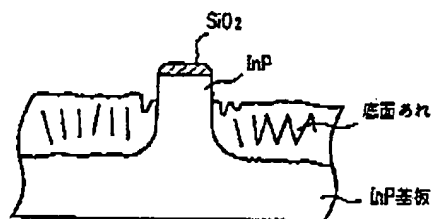


(13)

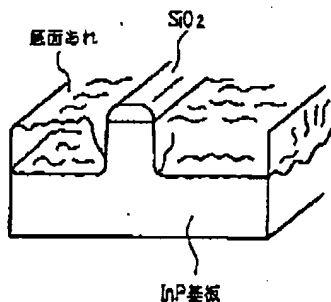
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【図2】

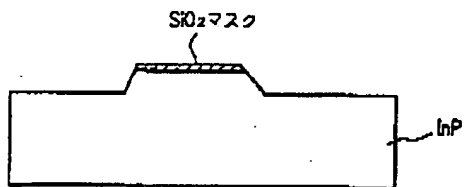
(a)



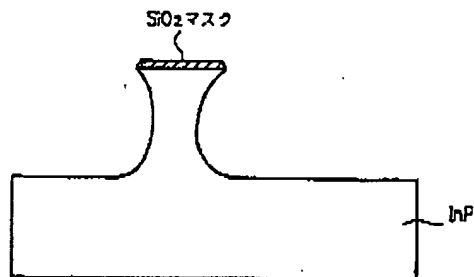
(b)



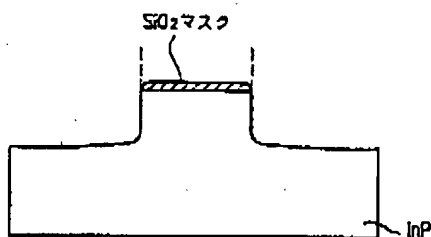
【図5】



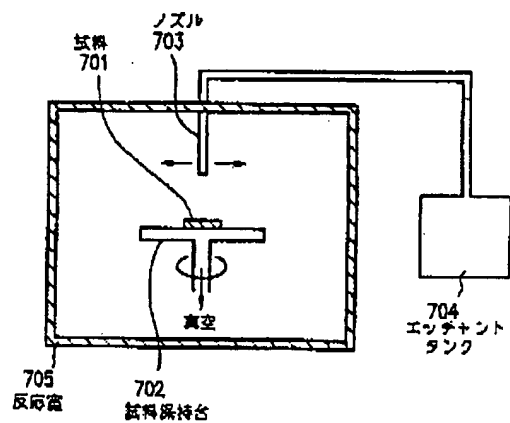
【図4】



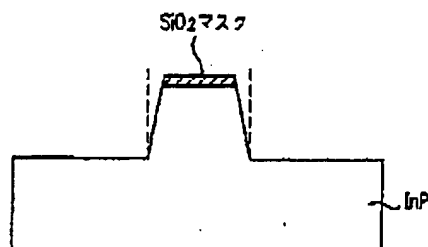
【図6】



【図7】



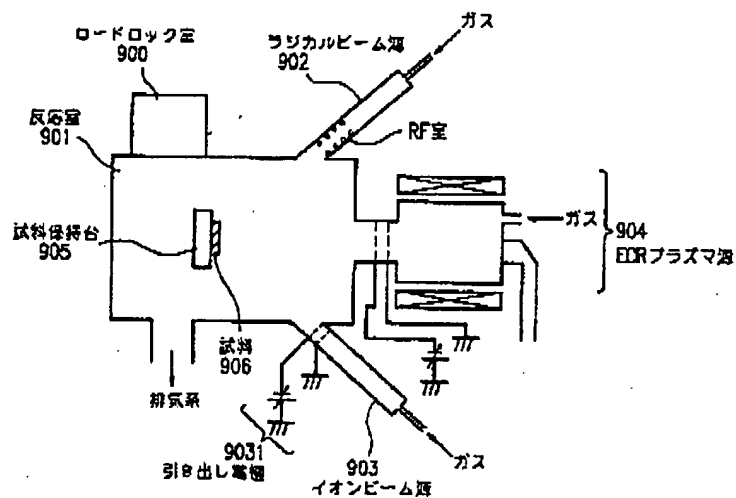
【図8】



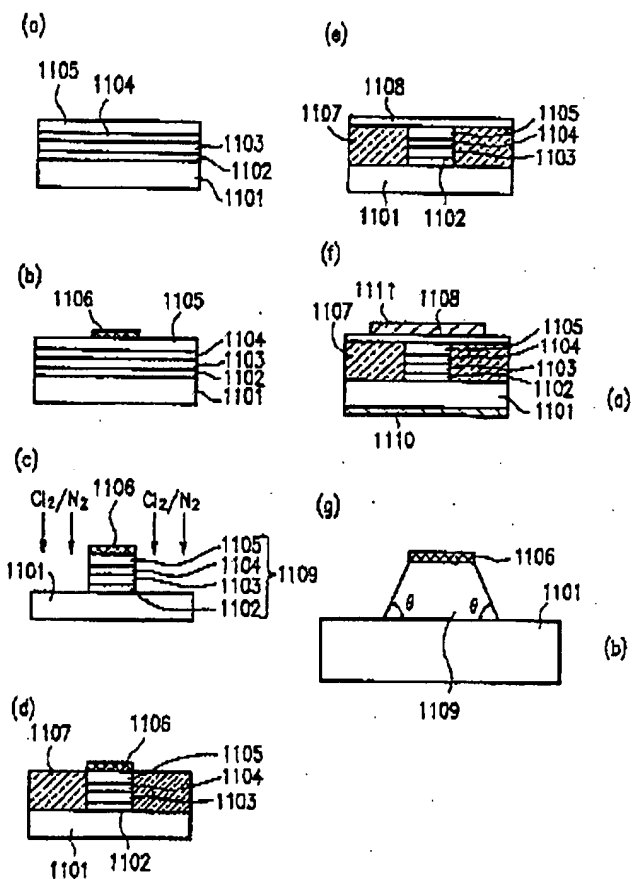
(14)

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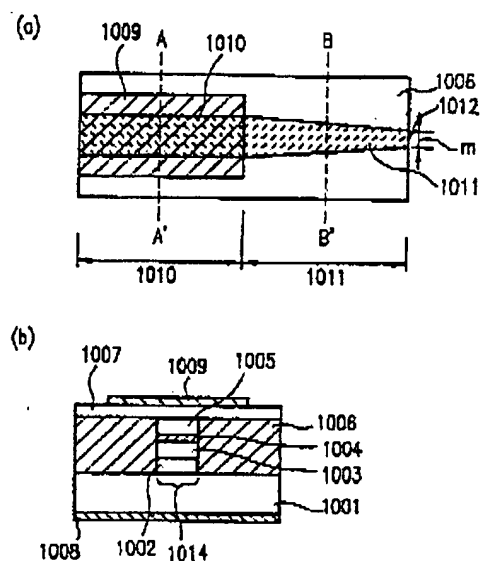
【図9】



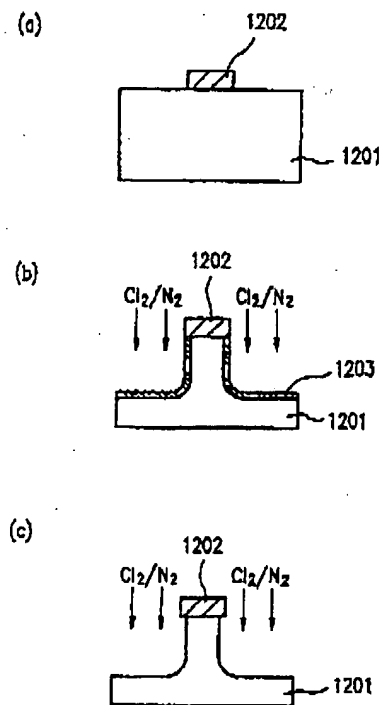
【図11】



【図10】



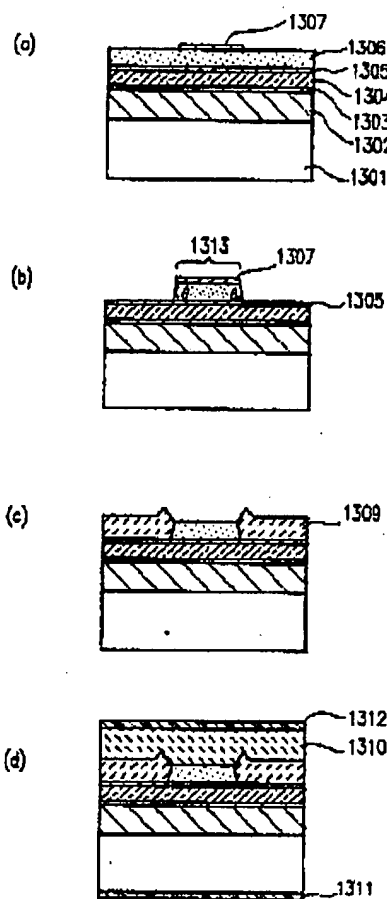
【図12】



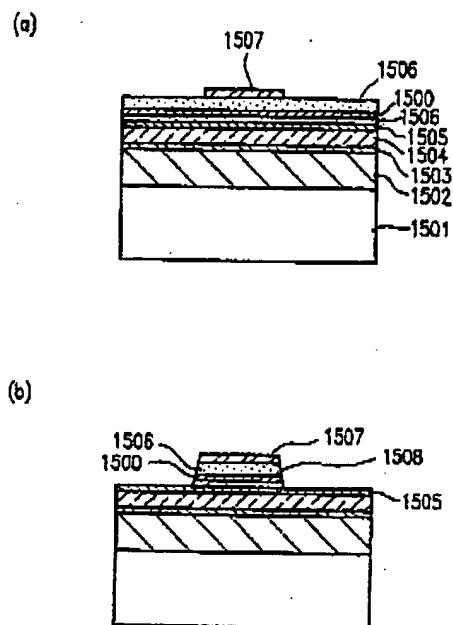
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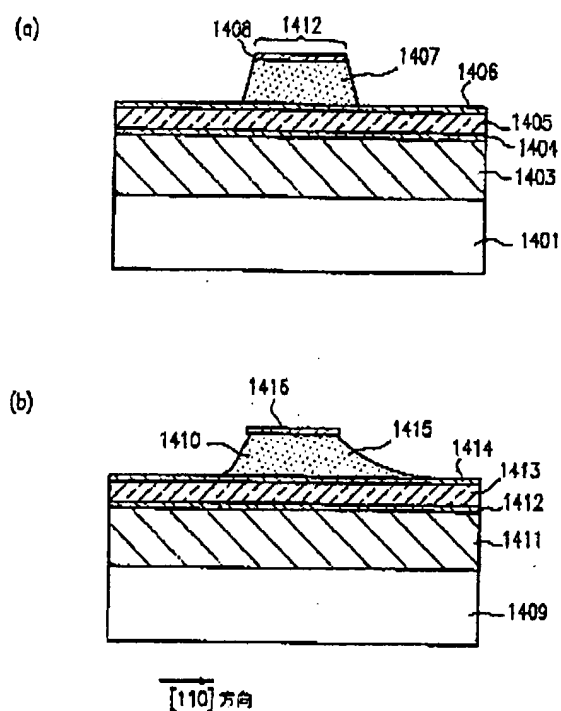
【図13】



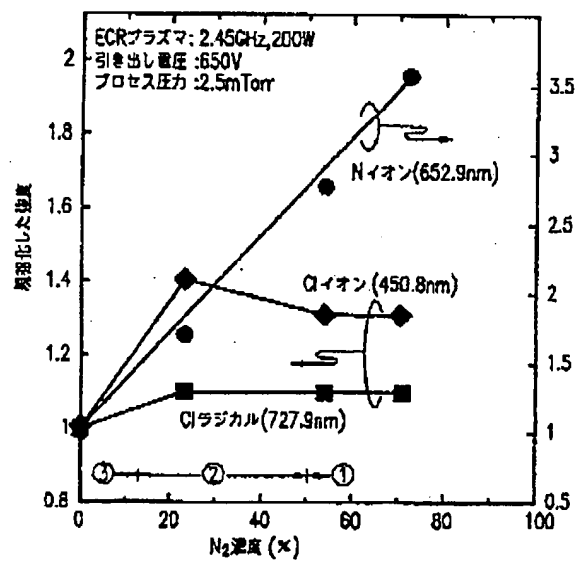
【図15】



【図14】



【図16】



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